PHYTOSOCIOLOGY, PRODUCTIVITY AND ENERGETICS OF A GRASSLAND IN BUNDELKHAND

THESIS SUBMITTED TO
BUNDELKHAND UNIVERSITY, JHANSI
FOR THE DEGREE OF

Doctor of Philosophy

IN

BOTANY

by

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DEPARTMENT OF BOTANY
D. V. COLLEGE
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1980

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SUPERVISOR'S CERTIFICATE

I hereby certify that the thesis entitled, "Phytosociology, productivity and energetics of a grassland in Bundelkhand" is an original piece of research work carried out by Shri Vijai Kumar Srivastava, under my guidance and supervision for the Degree of Doctor of Philosophy of the University of Bundelkhand. It is also certified that he attended the laboratories of Botany department, Saugar University, Sagar for more than 200 days.

(G. P. Mishra)

ACKNOWLEDGEMENTS

I wish to express my deep sense of gratitude and heartfelt thanks to Prof. G.P. Mishra, M.Sc.,Ph.D., F.T.E., Head, Department of Botany and Dean, Faculty of Life Sciences, University of Saugar, Sagar, under whose guidance and supervision this study was conducted. He had taken immense pain at every stage of this study.

I am greatly indebted to Dr. U.N. Singh, my colleague and co-supervisor for advice, constructive criticism and encouragement.

I am highly thankful to Dr. B.B. Lal, Principal, D.V. College, Orai for providing laboratory facilities to complete a part of the present work and for permitting me to persue the present work as a teacher candidate.

Thanks are due to Dr. W.U. Mullick, Ex. Vice-Chancellor, Bundelkhand University, for encouragement in various ways.

I am also very much thankful to the Officers of Forest department, Orai Division, for their help and co-operation during field studies.

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DECLARATION

I hereby declare that with the exception of the guidance and suggestions received from my supervisor Prof. G. P. Mishra, Ph.D., F.T.E., Head, Department of Botany and Dean, Faculty of Life Sciences, University of Saugar, Sagar, this is my original piece of work carried out in the Ecological research laboratories, Department of Botany, University of Saugar, Sagar and Department of Botany, D. V. College, Orai, for the Degree of Doctor of Philosophy.

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CHAPTER I

INTRODUCTION AND REVIEW

INTRODUCTION

The population has increased tremendously throughout the world in recent years. To cope with the population hazards, agriculture is being mechanised for maximum production. Man has also domesticated a large number of bovine population for the purpose of milk and meat. This livestock population get their daily forage from grasslands. Thus grasslands claim equal status given to our croplands.

Grasslands have greatly influenced mankinds history. The extent of man's dependence on grasslands throughout the world can be viewed from the 'UNESCO final report No. 6, 1972', because the man makes use of grazing and browsing birds and flocks as converters of plant resources to meat, wool, hair, milk and leather etc. His uses may be more varied than these.

The data presented in the food and Agricultural Production year book of the United Nations F.A.O. (F.A.O. 1973) illustrate the importance of grasslands for producing food for man throughout the world. Milk and meat production from grasslands have increased during past 10 years, at the world level milk production has increased 8% and meat production 25%. At the same time the area of grazing lands has decreased over the world, indicating intensification of grassland usage by livestock. Greater intensity of grassland

utilization will require more knowledge of the functional ecology of the systems.

Most grasslands of temperate Europe are recognized largely as artifacts and those of southern hemisphere are almost entirely tropical or subtropical. Many of the European and Japanese grasslands represent seminatural grasslands created and maintained by man. Some of these grasslands date back to the initiation of forest clearing, which in Europe occurred during Roman settlement in the first few centuries A.D.

Under tropical monsoonic climate of India grasslands are maintained by anthropogenic pressure(Misra, 1957 and Pandeya, 1961). Besides India Tropical grasslands are found in east and west Africa, central and south America and some areas of northern Australia. In India, since long, forests have been removed continuously as a result of which forest grasslands occur throughout the country. Grasslands derived from tropical forest may be particularly important in the next half century. Heavy flux of growth in these grasslands comes up during monsoon and distinct communities can be established in these forest grasslands on sound ecological principles (Pandeya, 1962, 64a,b and 1969). According to Misra and Joshi (1952) the grassland ecosystem replaces denuded forest area as seral stage and may be maintained as such in the

influence of various biotic factors. These tropical terrestrial systems are usually considered to be the assemblage of various annual and perennial grasses, forbs and herbs.

During the last half of the 19th century, the American Marsh (1864), the Frenchman Reclus (1874) and the Russian Woeikof (1949) raised cautions about man caused alteration of the environment, such as destruction of vegetation by cattle grazing, erosion and soil destruction caused by plowing. In the 20th century many workers have also cited ways of man caused instability in ecosystem specially to grazing land system, such as pausturage, plantation and cultivation. Collectively, perhaps some 40% of the earthland surface is used by grazing animals receiving the bulk of their year long diet from herbaceous plants, predominantly grasses (Van Dyne *et al.*, 1978).

In India, the grazing lands are different from other countries of the world, because there are no regular paustures or paddocks, in which the cattle eat and live. They graze freely either on noncultivable lands or in the nearby forest lands. As the sun moves towards west the animals return home and undigested material is ejected out either in the way or in their abodes. Thus the minerals are not cycled back in the grazing lands, nor a proper flow of energy is maintained, leading to a decline in the fertility of the grazing lands.

Continuous grazing results in the gradual depletion of grazing lands because most palatable grasses and forbs are grazed frequently exposing the ecosystem, in which less palatable or even unpalatable plants appear. Severe grazing also reduces the photosynthetic area which adversely effect the productivity and energy value. It also affects considerably the survival of the plants by its effect on reproduction and seed formation. Successive removal of aerial parts resulted in lowering the herbage production and root growth (Robertson, 1933). According to Maurya (1970) grazing scrapping and other biotic disturbances associated with human habitation have completely altered the physiognomy of the gangetic plains in northern India.

Thus on one hand because of fast deterioration of fertility under the ecoclimatic stress, the insect damage, wrong land use practices, and on the other hand the difference between requirement and present day supply of fodder for the present livestock population of our country, there is an immediate need for scientific understanding of the methods for restoring the original potentialities of organic production.

Recently, Yadav and Singh (1977) have reported about 14 million hectare of the grazing area for the cattle population in India, which is very small in comparison to the 160 million cattle head, out of which 40 millions are

livestock population only. Even then in our country specially in Uttar Pradesh, except the I.G.F.R.I. at Jhansi, no attention is being paid towards the improvement of fodder production to feed livestock and to provide nutrition to human beings in the form of milk and meat.

The magnitude of the importance increased many folds, as the area under present investigation comes under Drought Prone Areas Programme (D.P.A.P.) of the state government. Therefore, the present study is planned to evaluate: The structural and functional aspects of the grasslands under protection and grazing conditions; and the organic productivity of these systems and their forage yield.

REVIEW

Grasslands are important terrestrial systems, which are now due to their wide cover and definite physiognomy constitute 'Grassland biomes'.

Grasslands have been differentiated into prairies, steppes and savannas. These subdivisions are mainly based on the physiognomic appearance and general climate of the region. The basic differences between prairies and steppes is that, prairies are less humid than steppes (Van Dyne et al. 1973). The steppes are subhumid land formations of the temperate zone e.g. famous great plains of North America and cooler grasslands of Eurasia etc. Prairies have been

characterized by Ovington et al. (1963) as fairly open vegetation including tall grasses as dominant species and few shrubs. Savannas have been defined variously by different workers. According to Bourline and Hadley (1970), savanna is a type of tropical grassland formation, where grass substratum is continuous but it is interrupted by trees and shrubs here and there. Odum (1971) described savanna as a grassland with scattered trees, a type of community intermediate between grassland and forest. Savanna was also defined by Daubenmire (1972) as a strictly physiognomic term that contain scattered trees and shrubs above the grass layer.

A number of workers have putforward their views regarding Indian grasslands from time to time. According to Champion (1936), the stability of Indian grassland is controlled by several biotic agencies and is not the climatic climax. Ranganathan (1938) stated that grasslands of Nilgiri plateau are climatic climax community of the region, while Shankaranarayan (1958) described Talegon grassland of Western Ghat, as a product of regional climate. According to Ramam (1966) Indian grasslands are in secondary seral stage and may be very stable preclimax under the influence of fire and grazing. Ambashta et al. (1972) described grasslands of our country in general and of northern India in particular, are largely biotically controlled and represent the disclimaxes. While, Billore (1978) has

described the Indian grasslands as 'seral communities', produced as a result of temporary or permanent freedom from competition of woody plants.

The grasslands have been studied extensively in different parts of our country. In the begining of this century the observations on the grasslands were about its description and floristic composition. Later on experimental phase took lead over descriptive phase, in which autecology and synecology of species of grasslands and other communities were worked out. The important contributions were made by Chakradeo (1922), Bharucha and Dave (1944), Bharucha (1952), Shankarnarayan (1956), Dabadghao and Sikka (1961), Puri (1961) and Vyas (1964). Ranganathan (1938), Govindu and Thirumalachar (1952) and Shankarnarayan (1958) explored the south Indian grasslands. Ecological studies in eastern grasslands were conducted by Chatterjee *et al*. (1954), Raychoudhary and Biswas (1957). In Varanasi, Misra (1946) initiated ecological studies with floristic composition and other aspects of B.H.U. Campus. Ramkrishnan (1958) carried out autecological studies of various species of Varanasi region. Ramam (1960) investigated soil/root relationship in the grassland community of Varanasi. Pandeya (1950, 1952, 1953), Tiwari (1953), Misra (1955,1957) and Trivedi (1962) studied the structural aspects of grasslands of Sagar. Studies of reproductive capacity of grasses were conducted by Balapure (1954).

The production studies were initiated since 1964 and production potential has been extensively explored under I.B.P. Programme, sponsored by I.S.C.U. (1964) for 'The Biological basis of productivity and human welfare'. The I.B.P. has given direction and speed to the collection of data on production, energy flow, mineral and water cycling.

In temperate countries Weigert and Evans (1964) studied the primary production and the disappearance of dead vegetation on an old field in south Carolina. Dahlman and Kucera (1965) while working on root productivity in native prairies of Missouri, suggested a new term 'turnover'. Monk (1966) revealed the importance of root/shoot ratio. More information is available on primary productivity and turnover for grazing land ecosystems of temperate region-Odum (1960), Golley and Gentry (1965), McNaughton (1967), Jankowska (1968) and Beevington (1969). Much emphasis has been paid to system transfer function. It is defined by Grodins (1963), Golley (1966)-as the quantity by which system block multiplied the input to generate the output.

Important contributions by Indian ecologists towards production aspect of grassland communities have been made by Singh (1967), Choudhary (1967), Agrawal (1970), Maurya (1970), Tripathi (1970), Singh (1972a) and Singh (1972b) at Varanasi. A number of papers included in the proceedings of two symposia organized by the International Society

for Tropical Ecology in India (Misra and Gopal, 1968); Golley and Golley, 1972) also dealt with productivity and energetics of tropical system. Pandeya and Jayan (1970) studied various grasslands dominated by Cenchrus ciliaris at Ahmedabad. Joshi et al. (1971) reported the primary productivity of a few selected site at Pilani. Jain (1971) compared the Heteropogon grassland of Sagar with that of prairie, Gupta et al. (1972) worked on aboveground productivity in natural grasslands of Jodhpur. Ambashta et al. (1972) compared the primary production and turnover of certain protected grasslands of Varanasi. Varshney (1972) investigated the production of protected (Aerodrome) grassland at Delhi. A lot of work has been done on productivity and other functional attributes of grasslands at other places: Mall and Singh (1971, Ujjain), Singh and Yadav (1972, Kurukshetra), Misra (1973, Ujjain), Billore (1973, Ratlam), Asthana (1974, Gorakhpur), Naik (1974, Ambikapur), Das (1975, Allahabad), and Pandeya (1977, Varanasi).

More recently natural resource ecology school led by George Van Dyne has been doing good amount of work on system analysis in 'Grassland Biome' in U.S.A., as a successful model is believed to supply a great deal of information (Van Dyne et al., 1973). Innis (1973) opined that the system function is a dynamic approach to the study of grassland ecosystem. Lieth and Whittaker (1975) have summarized their reports for different ecosystems with the help of models in 'Primary production of Biosphere'.

Golley (1975) have reviewed the functional aspects of tropical grassland biome in 'Tropical Ecological Systems'. Innis (1978) has also reviewed the work done in different grassland biomes by simulation models. Ronald (1978) put-forward data on phenology and biomass dynamics.

Much work has been done in India on System Analysis of grassland biome by Pandeya _et al_. (1973) at Rajkot. Pandeya _et al_. (1977) have also compiled data of studies done on different aspects of grazing lands in western India.

Yadav and Singh (1977) have summarized the information on various aspects of the grazing land ecosystem of India. A detailed analysis of the primary producers of Indian grass-lands with respect to energy flow and nitrogen and phosphorus cycling has recently been made by Singh _et al_. (1977), under I.B.P. synthesis.

Under M.A.B. programme various structural and functional aspects have been worked out in a savanna stand of Varanasi by Singh (1978).

The grasslands of Bundelkhand region in the southern part of U.P. have not been explored in detail so far. However, I.G.F.R.I. Jhansi is carrying out researches on grasses in terms of their quality, food value, palatability, breeding, growth and physiology etc. Production studies of these grasslands have been done by Shankarnarayan and Dabadghao (1970) Vinod Shanker _et al_. (1973), and Pathak _et al_. (1974).

Gupta (1976) and Trivedi (1976) have also studied the grassland cummunities of Jhansi.

Very little work appears to have been done on the productivity of Dichanthium annulatum dominated communities in Bundelkhand region.

Therefore, a forest grassland dominated by Dichanthium annulatum has been undertaken to evaluate its phytosociological details, phytomass, photosynthetic structure, organic matter dynamics, energy status etc., of Bundelkhand region.

The data obtained in this study may help in understanding the production potentiality, which in turn may help in proper management, utilization of these grasslands for fodder and their sustained use for human welfare.

CHAPTER II

STUDY STAND AND CLIMATE

A. STUDY STAND

Stand Location

The study stands are located at Bohadpura forest, about five and seven kilometre respectively towards west of Orai (Lat. 25° 59' 30"N, Long. 79° 37' 30"E and 125 m above mean sea level).

Two stands were taken for study. Stand one was protected in 1972 by forest department under Drought prone areas programme of Government of Uttar Pradesh. Since then grazing has not been allowed but the grassland is auctioned every year and is harvested during the month of October/November. During the study period (1977-78) an area of 2 ha. was completely protected from all biotic interferences (Fig. 1). Stand second remained open for grazing throughout the year.

Bundelkhand region occupies a central position in the country. This tract of the country which is mostly hilly support a good growth of grassland. The area under investigation is a part of level land situated in a triangle between Yamuna river in North, Betwa river in south and Madhya Pradesh state in the west. The area of Orai town is 7363.92 ha. out of which 320.56 ha. is occupied by forest.

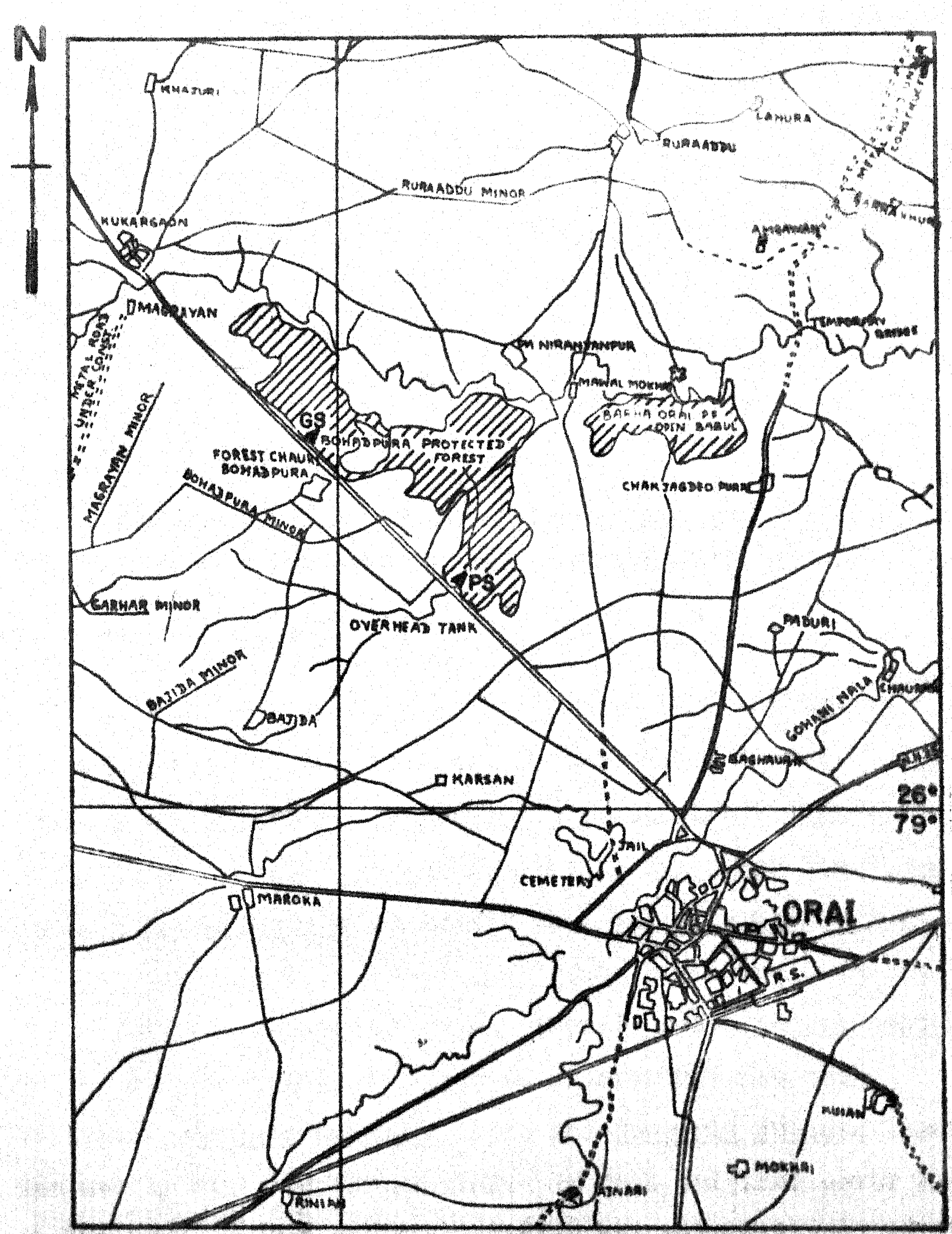


FIG. 1 - MAP OF ORAI SHOWING STUDY STANDS.

PS - PROTECTED STAND, GS - GRAZED STAND.

SCALE - 0 1 2 3 4 5 KM

M 1000 500 M TO 1 CM

The Terrain

With exception of southern marginal areas the entire Bundelkhand region is marked by undulating topography, that tends to become into a perfect level plain towards north (Orai). It shows every where gently undulated surface with occasionally flat topped ground. Bundelkhand plain also known as trans Yamuna plain which is divisible to three, -east, west running belts and Orai division comes under northern belt, which is the narrowest of the other two and confined along the banks of Yamuna in the form of high ground which represents the level of the ancient flood plain, but at present is badly cut into deep ravines.

Natural Vegetation

Bundelkhand an ecologically degraded region has an estimated area of 0.64 million hectares under forest (7.2%). *Tectona grandis* Linn., *Anogeissus pendula* Edgew, *Albizzia procera* Benth., *Albizzia lebbek* Benth., *Diospyros tomentosa* Rox., *Butea monosperma* (Lamk.) Taub., *Salmalia malabarica* (DC.) Schott & Endl., *Boswellia serrata* Rox., are found in small patches. *Acacia nilotica* (Linn.) Del., *Acacia catechu* Willd. are the principle types of acacias but not much utilized. *Carrisa carandus* Linn. and *Capparis decidua* Edgew. are mostly utilized for grazing. In Orai original cover has almost been removed for inhabitation and cultivation. Shrubs and grasses represent the secondary growth throughout the region.

Lithology (Geology)

The common rocks are sand stones, lime stones and shales. The peculiar features of immense geographical interest in this region are the long narrow serrated ridges termed as quartz reefs and dolarite dykes. In the north west and north east the geological system is covered by Ganga Yamuna alluvial deposits in the form of an 'embayment'.

The Soil

The most important soil groups of Bundelkhand are found in the northern low land (Orai). These are Mar, Kabar, Parua and Rankar, formed partly in situ and partly by transporting agencies, chiefly by the streams. Mar is a calcareous soil, predominantly blackish in colour, mixed with lumps of Kankar. It is friable and aerated. Kankar on the other hand is highly diffused. Parua the best known variety of the degraded red and yellow soil group is well aerated, friable and receptive to irrigation and favourable for various types of crops. Rankar is associated with flood plains subjected to gullying and erosion, so that calcium nodules are exposed at the sloping surfaces, rendering them unsuitable for cultivation.

The soil of the stands under the present investigation consists of sand, silt, clay and kankar in the following percentages: a- fine sand 2.75%, b- coarse sand 41.70%, c- silt 21.74%, d- clay 25.00% and e- kankar 8.81%.

Thus it is medium textured and sandy loam to loam. Amongst physical characters - the soil colour of the stands (as per Munsell colour Chart) is light olive brown or olive brown (value chrome) Hue 2.5y. 5/4. It is acidic in reaction.

Water holding capacity is measured as proposed by Pandeya, Puri and Singh (1968). The values of water holding capacity increases with depth though very little, at both the stands during growth period.

The amount of soil moisture depends on rainfall as moderated by topography and soil depth. The average value during best growth period reveal maximum soil moisture percentage in the month of July.

A detailed account of the soil (chemical and physical) is given in the Table II 1.

Results of chemical analysis of soil samples indicate that soil is medium in total nitrogen content and poor in available phosphorus content . They revealed maximum percentage in the uppermost layer (0 to 10 cm) of the soil.

B. CLIMATE

The region experiences a transitional climate between the marginal climate of East Coast (Bay of Bengal) and the tropical continental dry type of climate of west (Rajasthan).

The characteristic of the climate of this region is long, hot and dry summer season, less precipitation and a small

Table II 1: Physicochemical characteristics of soil of the two study stands.

Physicochemical characters	Protected stand (Depth in cm)			Grazed stand (Depth in cm)		
	0 - 10	10 - 20	20 - 30	0 - 10	10 - 20	20 - 30
pH	7.6	7.7	7.7	7.7	7.8	7.8
Water holding capacity (%)	39.54	40.71	41.21	42.69	43.62	43.74
Soil moisture (%)	18.76	22.90	24.81	18.09	21.04	23.52
Soil nitrogen (%)	0.068	0.059	0.035	0.055	0.038	0.035
Available phosphorus (%)	0.019	0.013	0.006	0.015	0.010	0.006
Organic carbon (%)	0.23	0.23	0.12	0.39	0.21	0.15

winter season. The year may be divided into three distinct seasons.

a- Rainy season (Last week of June to middle of October)

It is warm and wet.

b- Winter season (November to middle of March)

It is cool and dry.

c- Summer season (March to last week of June)

It is hot and dry.

The mean annual temperature of Orai is 24.8°C but mean monthly values considerably vary from their annual means (14.5 to 35.5°C) and consequently their ranges are high. On occasional nights temperature may fall down to a lowest minimum of 2°C. The intensity of the summer season increases with a very hot westerly dust laden winds called "Loo", which usually blow throughout May and June and the temperature continuously increases upto a highest maximum of 45°C in May.

Total annual precipitation comes to about 1186.8 mm of which 90% falls between July to October i.e. during wet summer when the temperature fluctuates around 30°C. The onset of mansoon takes place during the end of June with maximum rainfall during July and August. Some shallow westerly depressions cause occasional winter rains which take place by the end of December upto the end of February or March, winter accounts for only 2% of the annual rainfall.

When annual temperature and precipitation are considered together the area is warm and dry i.e. dry subhumid.

With respect to wind, because intensity of rains and temperature variation will depend upon the direction of wind, it blows over the area running from Bay of Bengal obliquely South East to North West direction in July. In winter months the direction of winds changes from North West to South East. During summer the wind is westerly with a maximum velocity of 5.3 Km per hour in May. Percentage relative humidity (mean monthly) of the area vary from 22.2 to 73%.

The details of the climate are given in Table II 2. According to Gaussen (1960) the effectiveness of climatic factors like temperature, precipitation and length of dry period can be understood in a better way by means of Ombrothermic diagram (Fig. 2). This is done by bringing out the elements on a graph. On the abscissa are marked the months, on ordinates to the left the temperature and to right the rainfall.

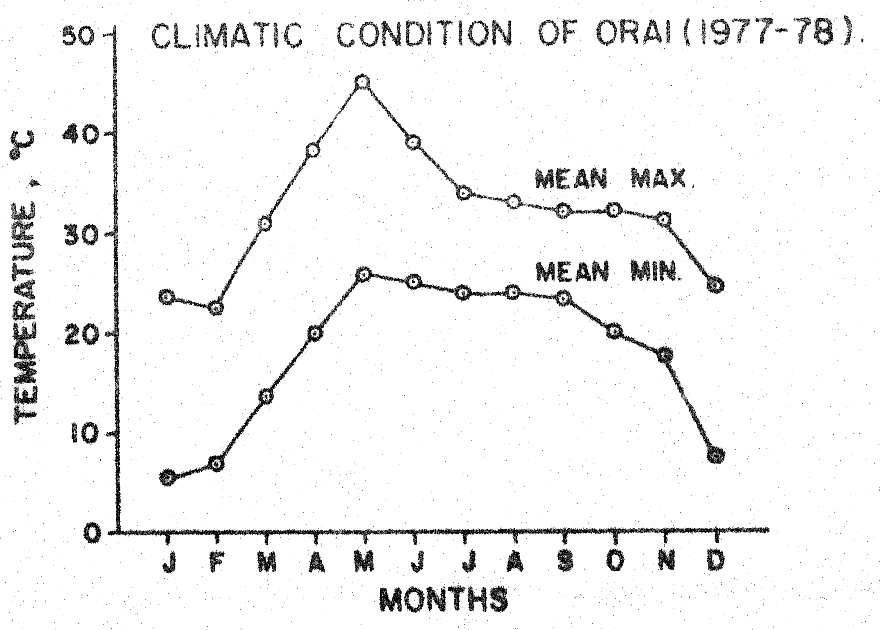
For tropical regions, where the mean monthly temperature is about 25°C, rainfall under 50 mm, would classify a month as dry. Thus the Ombrothermic conditions of the area revealed 8 dry months and 4 wet months during a year.

Solar Radiation

Solar radiation was not recorded at Bohadpura (Orai). Therefore, the mean value of Patna (Lat. 25°35'N) and Jodhpur (Lat. 26° 15'N) stations has been considered here for

Table II 2: Climatic data of Bohadpura (Orai) 1977-78

Months	Temperature °C			% Relative humidity			Wind velocity Km/hr	Rainfall (mm)	Incident Energy
	Mean max.	Mean min.	Mean month.	Mean morn.	Mean even.	Mean month.	Mean month.	monthly	K cal/m^{2}x10^3
1977									
July	34.0	24.1	29.0	78.0	67.0	72.0	2.0	615	67.73
August	32.8	23.9	28.8	73.7	72.5	73.1	2.8	194.8	52.70
September	31.9	23.5	27.7	66.5	66.7	66.6	2.9	169.7	52.20
October	32.1	20.0	26.0	60.0	52.0	56.0	1.8	69.0	64.63
November	31.1	15.0	23.0	50.0	38.0	44.0	1.7	3.4	50.40
December	24.5	7.6	16.0	57.5	43.8	50.6	2.0	5.0	48.20
1978									
January	23.5	5.5	14.5	51.8	45.7	48.7	2.0	8.4	53.78
February	22.4	6.8	14.6	44.3	46.3	45.3	3.0	2.0	59.64
March	30.7	13.6	22.0	50.6	38.6	44.6	3.0	19.3	67.89
April	38.0	20.1	29.0	37.3	18.0	27.6	3.5	1.0	76.80
May	44.9	26.2	35.5	25.4	19.0	22.2	5.3	-	82.46
June	39.2	25.0	32.1	50.0	40.6	45.3	4.4	99.2	75.90



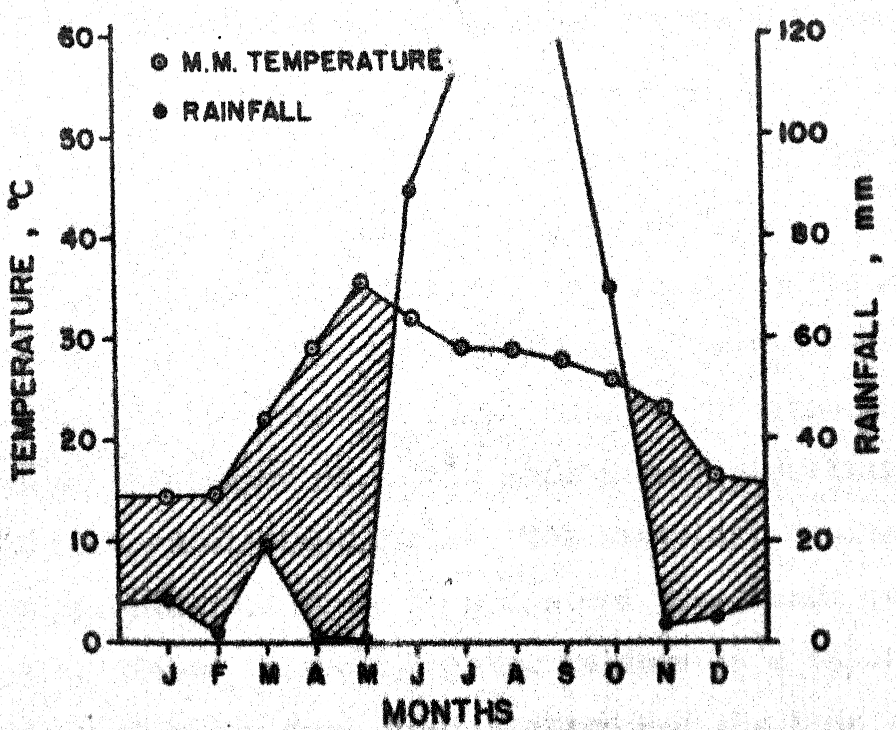


FIG:2 - OMBROTHERMIC DIAGRAM.

calculation of total incident solar energy because the geographical situation of Bohadpura, Orai (25^{o} 59'N) is approximately in between the above two stations.

Ecoclimate

Climate of an area in relation to growth of vegetation is measured in the form of precipitation, wind velocity, humidity, temperature etc. Any single factor of climate does not give a clear picture about the exact climate of an area in relation to the growth of vegetation. According to Subramanyam (1958) it is not possible to say that a climate is moist or dry from precipitation alone. These measurements also do not provide the water need of a given vegetation. Water need of a given region is the total amount of water required for full use of vegetation including transpiration as well as direct evaporation from soil surface. Thus the combined evaporation from the soil surface and transpiration from plant called 'Evapo-transpiration', represents the transport of water from the earth back to the atmosphere, the reverse of precipitation. This atmospheric circulation is a part of the Hydrological cycle. The numerical estimate of this part of Hydrological cycle in space and time leads to the concept of 'Water Balance'. Water Balance is a balance between the income of water from precipitation and the loss of water by evapo-transpiration, surface run-off and infiltration. The water balance equation after Thornthwaite is:-

Ppt = Potential evapo-transpiration - deficit+surplus

= Storage change (amount of water temporarily stored in soil)

Potential evapo-transpiration as proposed by Thornthwaite (1948) is defined as the amount of water that would evaporate and transpire from a vegetation if soil moisture were always available in sufficient amount for optimum use. It is a climatic balance since precipitation and evapo-transpiration are active factors of climate.

On the basis of the potential evapo-transpiration (P.E.) Thornthwaite tried to obtain moisture index (Im), from annual water surplus and water deficit. The P.E. Index represents water need of a vegetation and is calculated from mean monthly temperature of the area and latitude.

The whole computation of water balance is carried on by tables and Nomograms, as proposed by Thornthwaite (1948) and Thornthwaite and Mather (1955). Subramanyam (1955 to 1959) has published a series of papers on this aspect in India. Pandeya et al., has computed the water balance of atleast 8 stations of Western India in 1973 including Jhansi station of Bundelkhand Division.

In the present study the water balance of Orai station for Bohadpura is computed on the above pattern as per the method proposed by Thornthwaite and Mather (1955) (Table II 3). It is evident by the table that A.E. was governed by the amount of water available for plant growth and soil moisture storage. In the rainy season, when there was sufficient water for plant growth and soil moisture storage, rates of actual

Table II 3: Computation of Water Balance of Orai (1977-78).

Lat. N 25° 59' 30"N Long. E 79° 37' 30" Ht. 125m.

	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Annual
T°C	29.0	28.8	27.7	26.0	23.0	16.0	14.5	14.6	22.0	29.0	35.5	32.1	
i	14.32	14.17	13.36	12.13	10.08	5.82	5.01	5.07	9.42	14.32	19.45	16.70	139.85
U.P.E.	15.54	15.38	14.53	12.0	8.0	1.4	4.5	0.6	6.4	15.54	18.37	17.35	
P.E.	182	172	148	119	73	13	5	5.3	66	165	211	198	1357.3
Ppt (mm)	615	194.8	169.7	69	3.4	5.0	8.4	2.0	19.3	1.0	0	99.2	1186.8
P - P.E. = △	+433	+22.8	+21.7	-50	-69.6	-8	+3.4	-3.3	-46.7	-164	-211	-98.8	
≤ △	+433	+455.8	+477.5	-50	-119.6	-127.6	-131.0	-134.3	-181.0	-345	-556	-654.8	
St	300	300	300	-254	-200	-195	-193	-191	-163	-94	-46	-33	
△ St	+267	0	0	-46	-54	-5	-2	-2	-28	-69	-48	-13	
A.E.	182	172	148	115	57.4	10	5	4	47.3	70	48	112.2	970.9
W.D.	0	0	0	4	15.6	3	0	1.3	18.7	95	163	85.8	386.4
W.S.	166	22.8	21.7	0	0	0	0	0	0	0	0	0	210.5
R.o.	83	11.4	10.85	0	0	0	0	0	0	0	0	0	105.25

T°C = Mean monthly temperature
i = Heat index

U.P.E. = Unadjusted potential evapotranspiration
P.E. = Potential Evapotranspiration
Ppt = Mean monthly precipitation
≤ △ = Summation Data (Potential water loss)

S.T. = Storage
W.D. = Deficit
W.S. = Surplus
R.o. = Run off
A.E. = Actual evapotranspiration

evapo-transpiration were found maximum. By the end of rainy season (October) when precipitation was lesser than P.E., a decrease in the rate of A.E. was recorded and this decrease was continued till January/February. When soil moisture is at field capacity or above i.e. in the growing period (July to September) actual and potential transpiration are the same, all precipitation above the water need is counted as surplus (S). The annual value of water surplus comes to 21 cm. This surplus water is totally spent in soil moisture recharge. When precipitation fall below the water need i.e. P.E. or actual evapotranspiration becomes less than the P.E. (October to June), this difference is the water deficit (D), the annual value is 38.6 cm. The major deficit is reported in April and May. In the graph (Fig. 3) monthly course of P.E. and A.E. is compared with the precipitation showing clearly the S and D regions.

The net water surplus (S - D) for the whole year, the negative value is obtained (-17.59 cm).

On the basis of moisture index value (-1.70) the area of the study can be classified as dry subhumid (C 1) which is further classified on the basis of thermal efficiency, i.e. P.E. (135.7 cm) as second mega-thermal (A_2). The value of summer concentration of thermal efficiency (SCTE) (43.5) comes to a_2' symbol which clearly indicates that lower SCTE value means high temperature uniformally month after month.

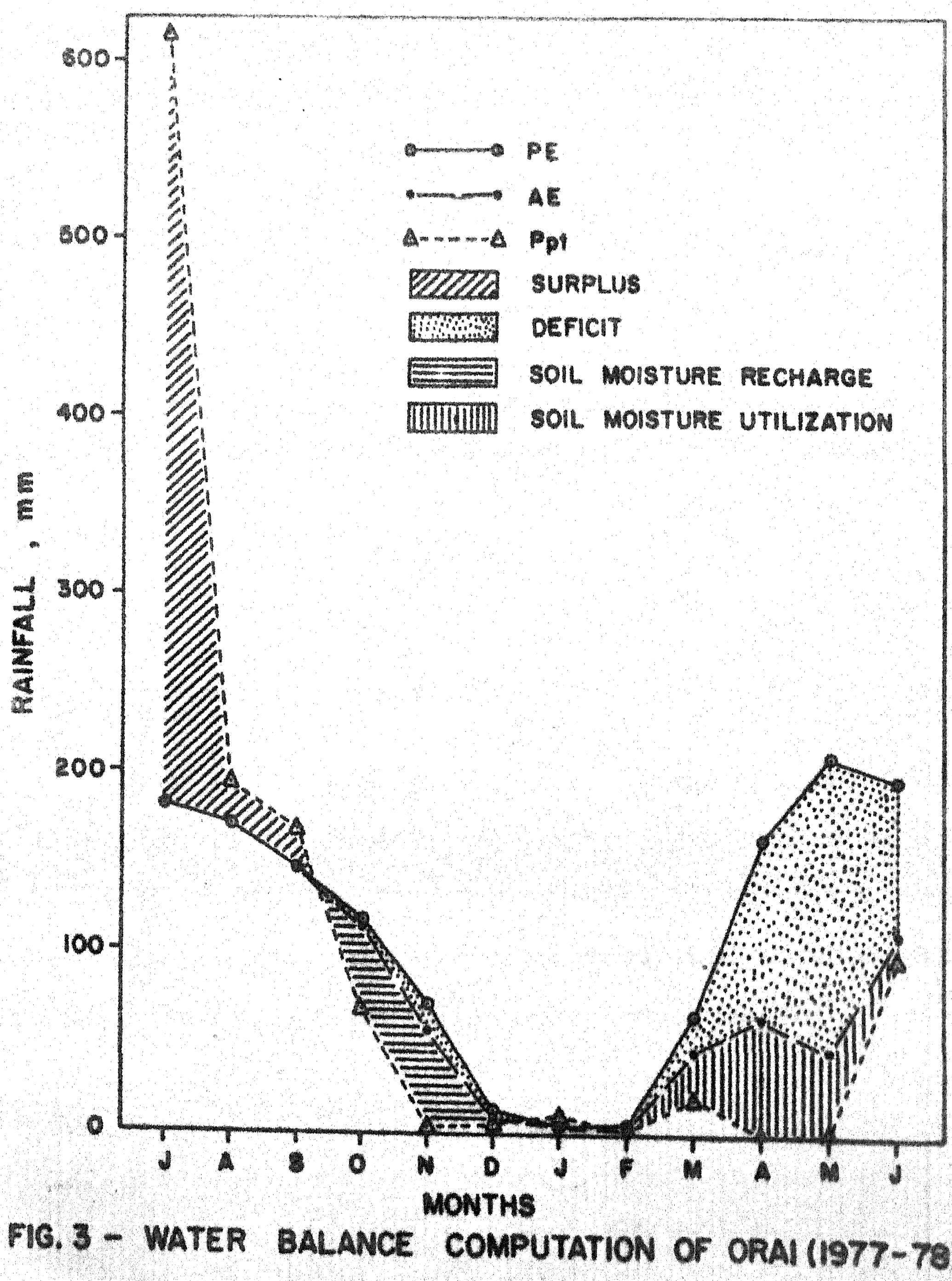


FIG. 3 - WATER BALANCE COMPUTATION OF ORAI (1977-78)

SCTE may be defined as the rates of thermal efficiency for the 3 summer months to the total annual efficiency expressed as percentage. Thus eco-climatic formula of the study area comes to $C_1\ A_2'\ a_2's$. Here the small s indicate summer water defficiency.

The various climatic indices worked out are :-

Potential evapotranspiration (PE) = 135.7 cm = 1357 mm

Humidity Index $(Ih) = \frac{S}{PE} \times 100 = 15.5$

Aridity Index $(Ia) = \frac{D}{PE} \times 100 = 28.46$

Moisture Index $(Im) = Ih - 0.6 \times Ia = -1.70$

Summer Concentration of Thermal Efficiency (SCTE) = 043.5

Total annual precipitation is 1186.8 mm, and because of large amount of Radiant energy received (Table II 2), the P.E. is always higher than the precipitation (Ppt), except in the month of July, August and September and to some extent in January, when it almost compensates each other.

CHAPTER III

STAND STRUCTURE

Phytosociological analysis of a plant community is the first and foremost basis of study of any piece of vegetation.

A number of workers have studied various grasslands of this country from phytosociological point of view e.g. Misra (1946, Varanasi), Pandeya (1952, Sagar), Tiwari (1953, Sagar), Shankarnarayan (1956, Bombay), Singh (1967, Varanasi), Bharucha and Shankarnarayan (1958, Western Ghat), Shankarnarayan and Dabadghao (1970, Jhansi), Jain (1971, Jabalpur), Jain (1971, Sagar), Singh (1972b, Varanasi), Gupta *et al*. (1972, Jodhpur), Varshney (1972, Delhi), Misra (1973, Ujjain), Billore (1973, Ratlam), Das (1974, Raipur), Naik (1974, Ambikapur), Singh and Yadav (1974, Kurukshetra), Gupta (1976, Jhansi), Trivedi (1976, Jhansi), Mehta (1977, Ujjain), Singh (1978, Varanasi) and Agnihotri (1979, Mandla).

In the present study two stands i.e. protected and grazed, have been studied quantitatively and qualitatively. The study of species composition of the vegetation is a prerequisite to the understanding of species diversity as it is one of the major aspects of the various terrestrial plant communities.

METHODS

For studying the structure of stands the minimum size of quadrate i.e. 50 x 50 cm was fixed following the species area curve method. During sampling a total of 50 quadrats were laid on a line at an interval of every five metres. The species and their number of individuals occurring in each quadrat were recorded. In case of grasses a single tiller was considered to be an individual plant. The basal area at the point of emergence for constituent species was measured. Various structural parameters i.e. frequency, density, abundance, basal cover, have been calculated for each species occurring in the stands studied. Three analytical characters i.e. relative frequency, relative density and relative basal area of each species were determined. Importance value index was then calculated for each species (Curtis and Cottom, 1962). The formulae used for the determination of these characters are as follows:-

$$\text{Relative Frequency (R.F.)} = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100$$

$$\text{Relative Density (R.D.)} = \frac{\text{Density of a species}}{\text{Density of all species}} \times 100$$

$$\text{Relative Basal area (R.B.)} = \frac{\text{Basal area of a species}}{\text{Basal area of all species}} \times 100$$

$$\text{Importance Value Index (IVI)} = \text{R.F.} + \text{R.D.} + \text{R.B.}$$

The Diversity index of the community was determined by using the formula of McIntosh (1967).

$$\text{Diversity Index (D.I.)} = \sqrt{\sum^{S} n\,i^2} \quad i = 1$$

Where,

S = Number of the species and

n = Individuals in each species.

The sampling was made once in each of the three seasons of a year i.e. rainy (in August), winter (in January) and summer (in April) on both the stands. After an extensive survey of the area under study during the year 1977-78, a list of the species was prepared.

PHYTOSOCIOLOGY

Species Composition

Difference in species composition of the vegetation on the two stands is quite evident from Table III 1. The annual grasses occupying the protected stand were - *Chloris barbata*, *Digitaria marginata* and *Manisuris granularia*. While *Sporobolus diander*, *Echinochloa colonum*, *Digitaria sanguinales*, *D.stricta*, *D. adscendens* and *Dactyloctenium aegyptium* were only present on grazed stand.

Amongst nongrasses, the species which were conspicuous by their presence on protected stand were: *Alysicarpus rugosus*, *A. vaginalis*, *Biophytum sensitivum*, *Enicostema verticillata*,

Table III 1: Seasonal variations in species composition on the two stands

Species	Season						Life form
	Rainy		Winter		Summer		
	P.S.	G.S.	P.S.	G.S.	P.S.	G.S.	
Achyranthus aspera Linn.	+	+	+	-	-	-	T
Aerua lanata Juss.	+	+	-	-	-	-	T
Alternanthera sessilis Br.	-	+	-	+	-	+	T
Alysicarpus monilifer D.C.	+	+	-	+	-	+	T
A. rugosus D.C.	+	-	+	-	+	-	T
A. vaginalis D.C.	+	-	+	-	-	-	T
Andropogon pumilus Roxb.	+	-	-	-	-	-	T
Apluda mutica Linn.	+	-	+	-	-	-	H
Aristida adscensionis Linn.	+	+	+	-	-	-	T
Anthroxon lancifolius Hochst.	-	+	-	-	-	-	T
Biophytum sensitivum D.C.	+	-	-	-	-	-	H
Blepharis molluginifolia Pers.	-	+	-	-	-	-	T
Blumea oxyodonta D.C.	+	+	+	+	-	-	T
Boerhaavia diffusa Linn.	+	+	+	+	+	+	H
Bonnaya brachiata Link and Otto.	-	+	-	-	-	-	T
Borreria hispida (Linn.) Schum	+	-	+	-	-	-	T
Brachiaria reptans Gard.et. Hubb.	+	+	-	-	-	-	T
Cassia aleinii W & A	+	+	-	-	-	-	T
C. tora Syn. C. obtusifolia W & A	+	+	+	-	-	-	T
Centella asiatica Urban	+	-	-	-	-	-	H
Chloris barbata L. Sw.	+	+	-	-	-	-	T
C. myosuroides Hook.f.	+	+	-	-	-	-	T
Convolvulus pleuricaulis Chois. Var. macra C.L.	+	+	+	+	+	+	H
Corchorus acutangularis Lamk.	+	+	-	-	-	-	T
Crotolaria prostrata Roxb.	-	+	-	-	-	-	H
Cyperus haspens C.K.	+	+	-	-	-	-	Cr
C. kyllinga Syn. Kyllinga monocephala Roxb.	+	+	-	-	-	-	Cr
Dactyloctenium aegyptium Beauv.	-	+	-	-	-	-	T
Desmodium triflorum D.C. var. minus D.C.	+	+	+	+	-	+	H
Desmostachya bipinnata L. Stapf.	+	+	+	+	+	+	Ch
Dichanthium annulatum (Forsk.) Stapf.	+	+	+	+	+	+	Ch
Digitaria adscendens Henr.	-	+	-	-	-	-	T
D. marginata Link.	+	-	-	-	-	-	T
D. sanguinates (L.) Scop.	-	+	-	-	-	-	T
D. stricta Roth.	-	+	-	-	-	-	T
Echinochloa colonum (L.) Link.	-	+	-	-	-	-	T
Eleusine indica Gaertn.	+	+	-	-	-	-	T
Elytraria crenata (Vahl.)var. T.acaulis	+	+	+	+	-	+	T
Enicostema verticillata (Linn.)Engl.	+	-	+	-	+	-	T
Eragrostris gangetica Steud.	+	+	-	-	-	-	T
E. tenella R.& S.	+	+	-	-	-	-	T
Euphorbia hirta L.	+	+	+	+	+	+	T

Table III 1 contd.-

Species	Rainy P.S.	Rainy G.S.	Winter P.S.	Winter G.S.	Summer P.S.	Summer G.S.	Life form
Euphorbia hypersifolia L.	+	+	+	+	+	-	T
E. thymifolia L.	+	+	-	-	+	-	T
Evolvulus alsinoides L.	+	+	+	+	+	+	H
Fimbristylis bisumbellata Forsk.	+	+	-	-	-	-	Cr
F. junciformis Nees.	+	+	+	+	+	+	Cr
F. quinquangularis Vahl.	-	+	-	-	-	-	Cr
Glossocordia linearifolia Cess.	+	-	-	-	-	-	T
Heteropogon contortus L. Roem. & Schult.	+	-	+	-	+	-	H
Indigofera cordifolia Heyne.	+	+	+	-	-	+	T
I. trifoliata Linn.	+	-	-	-	-	-	T
Ipomoea pestigridis Linn.	+	+	-	-	-	-	H
Iseilema laxum Hack.	+	+	+	+	+	+	T
Justicea simplex Don.	+	+	+	+	+	-	T
Launaea aspleniifolia H.K.f.	-	-	-	-	+	-	H
Lepidagathis cristata var. rupestris Willd	+	-	-	-	-	-	H
Leucas aspera Spr.	+	-	-	-	-	-	T
Lindernia crustacea Linn.	-	+	-	-	-	-	T
Ludwigia parviflora Roxb.	-	+	-	-	-	-	T
Melilotus indica All.Syn.M.parviflora Desf.	-	+	-	-	-	-	T
Manisuris granularis Willd.	+	-	-	-	-	-	T
Milotheria maderaspatana Cog.	+	-	-	-	-	-	T
Murdania vaginatum	-	+	-	-	-	-	T
Oldenlandia corymbosa L.	+	+	-	+	-	-	T
Orthosiphon pallidus Royle. Ex. Benth.	+	-	+	-	+	-	T
Panicum humile nees. ex. Stend.	+	+	-	-	-	-	Ch
Pavonia zeylanica Cav.	+	-	-	-	-	-	T
Paspalidium flavidum (Retz.) A. camus	+	+	-	-	-	-	T
Peristrophy bicaliculata Nees	+	+	+	+	-	-	H
Phyllanthus maderaspatana L.	+	+	-	-	-	-	T
P. fraternus Webster	+	+	-	-	-	-	T
Physalis minima var. indica L.	+	+	-	-	-	-	T
Polygala erioptera D.C.	+	-	-	-	-	-	T
Psida spinosa Linn.	+	+	+	+	+	+	T
Rhyncosia minima D.C.	+	-	-	-	-	-	H
Rungia repens Nees	-	-	+	+	+	+	T
Setaria glauca L. Beauv.	+	+	-	-	-	-	T
Sporobolus diander Beauv.	-	+	-	-	-	-	T
Tephrosia tenuis Wall.	+	-	-	-	-	-	T
Themeda quadrivalvis (Linn.) O. Ktze.	+	-	+	-	+	-	H
Tridax procumbens Linn.	+	-	+	-	+	-	T
Triumfetta rhomboidea Jacq.	+	+	+	-	-	-	T
Vernonia cinerea Less.	-	-	+	-	-	-	T
Vicoa vestita Benth. (Innulavestita)Wall.	+	-	+	-	-	-	T
Zornia gibbosa Spanoghe.	+	+	-	-	-	-	T

T = Therophytes Cr = Cryptophytes H = Hemicryptophytes Ch = Chaemophytes

+ = Presence - = Absence P.S.= Protected stand G.S. = Grazed stand

Glossocordia linearifolia, Lepidagathis crystata, Orthosiphon pallidus, Pavonia zeylanica, Tephrosia tenuis and Wicoa vestita. Whereas the nongrasses present on grazed stand were those of Alternanthera sessilis, Blepharis molluginifolia, Bonnaya brachiata, Crotolaria prostrata, Lindernia crustacea, Ludwigia parviflora and Murdania vaginatum.

Perennial grasses e.g. Heteropogon contortus and Themeda quadrivalvis were only recorded on protected stand and rest of the species given in Table III 1 were almost common to both the stands.

Thus the annual and perennial species of common and frequent occurrence to both the stands were:- Cassia tora, Dichanthium annulatum, Desmostachya bipinnata, Evolvulus alsinoides, Fimbristylis junciformis, Iseilema laxum and Paspalidium flavidum etc.

Table III 2: Seasonal changes in the total number of species occupying the two stands.

Studied	Rainy	Winter	Summer
Protected stand	67	32	20
Grazed stand	59	19	15

On season wise break of the species (Table III 2) comparatively higher number of species (67) emerged out

during growing period i.e. in rainy season on protected stand than the species (59) on stand which was open for grazing. On both the stands a total of fourty three species were common . The number of species declined upto 32 and 19 on protected stand and grazed stand respectively during winter season due to the death of most of the annual grass and nongrass compartments. However, two new species viz., Vernonia cinerea and Rungia repens were added on protected stand and only the latter on grazed stand. During summer season the total number of species further declined upto 20 and 15 on the two stands respectively with only the addition of a new emergent on protected stand i.e. Launea aspleniifolia. The gradual decline in the total number of species occupying both the stands from winter onwards may be probably due to atmospheric temperature fluctuations and gradual soil moisture depletion upto summer months.

Phenology

Phenological observations are helpful in the understanding of important events during the life cycle of a plant. First few showers in the last week of June initiate tillering in annual and perennial species. In annuals tillers are given out from the seeds and/or seedlings whereas the perennating parts such as rhizome and runners etc. produce tillers in perennial species in addition to those arising from seedlings. Most of the annuals germinate in the month of June but the

perennials keep on germinating till August. The former enter flowering by August/September after their vegetative growth and produce fruits and seeds in September/October – then die and perish due to completion of their life cycle leaving behind their seeds to perennate.

The period from month of September to November is the period of flowering, fruit setting and seed setting in perennials, which survive in dry and unfavourable period through their underground perennating organs. Perennials also show tillering due to winter rains i.e. in January and February. However, in some of the perennials like D. annulatum and D. bipinnata only one flush of flowering was observed.

Life Forms and Phytoclimatic Spectrum

Earlier Jones (1936) has stated that Raunkiaers Biological Spectrum is valuable in expressing differences and similarities in communities. The general appearance of a plant community is caused more by the life form of the dominant species than by any other qualitative characteristics of the vegetation.

Cain (1950) has emphasized that the life form system of Raunkiaer on a physiognomic basis can best be applied to describe the vegetation of a community, because the climate of the stand and to a certain extent the effect of biotic operations are revealed by the classification in the various life form classes (Pandeya, 1953). Therefore, for describing

the vegetation of various regions Bharucha (1952) and many others have used Raunkiaer's life form Classes.

Table III 3: Biological spectra for the two stands studied* as compared with the Raunkiaer's normal spectrum.

Studied	Percentage of total species			
	Chaemo-phytes	Hemicryp-tophytes	Crypto-phytes	Thero-phytes
Protected stand	4.3	21.4	5.7	68.6
Grazed stand	5.0	11.9	8.5	74.6
Raunkiaer's normal value	9.0	26.0	6.0	13.0

* Percentage have been calculated without including Phanerophytes unlike Raunkiaer's (1934).

A comparison of the percentage distribution of various Life Forms in protected and grazed stands (Table III 3) with normal spectrum (Raunkiaer's, 1934), reveals that percentage of Hemicryptophytes and chaemophytes was lower and cryptophytes was approximately equal on both the stands than that of the normal spectrum. The percentage of therophytes was more than five fold (68.6 and 70%) on both the stands than the normal Raunkiaer's value (i.e. 13%) which indicate that the area of the study experienced a long dry season during a year.

Species Diversity

Species diversity has been considered as an index for the survival value to the community which lies in increased stability. Larger the number of species, the greater will be the possibility for community adaptation to changing climatic conditions and/or other factors as the number of species reflects the genepool and adaptation potential of the community (Odum, 1963). The species diversity is quite variable within and between the ecosystems.

The Phytosociological studies have been made seasonally in the present investigation and the seasonal values of Diversity Index have also been averaged to get separate D.I. values for both the stands on an annual basis.

Table III 4: Seasonal and average annual Species Diversity Indices for two stands

Season	Protected	Grazed
Rainy	536.62	286.23
Winter	433.18	52.01
Summer	169.29	37.28
Annual	379.69	125.17

On perusal of this table, it is evident, that the diversity in species composition was maximum in rainy season on protected (536.62) and grazed (286.23) stands, which decreased gradually in winter and reached upto minimum (i.e. 169.29 and 37.28 on the two stands respectively) by the summer season. Seasonal and annual values of diversity indices were relatively greater on protected stand than on the grazed stand. It indicates that the diversity in species composition was more pronounced on protected stand than on the grazed stand.

Parameters of Floristic Composition

Frequency

Frequency reveals the degree of the dispersion of a species in an area and is expressed in terms of percentage. After sampling a large area, Raunkiaer (1934) grouped the species into five frequency classes viz., A, B, C, D and E on the basis of their percentage occurrence in the area. His 'Law of Frequency' stated that the number of species in frequency class A is greater than B, B is greater then C, C is greater or lesser than D and D is always lesser than E i.e. $A > B > C \gtreqless D < E$.

It is interesting to note that in the present study the percentage frequency of the various species grouped according to Raunkiaer's frequency classes was quite dissimilar than that of the normal frequency spectrum proposed

by Raunkiaer (1934). The percentage of species in the five frequency classes resulted in such an order as:

A > B > C > D $\gtreqless$ E for both the stands. It indicates towards the heterogeneous nature of both the stands studied, which is quite obvious as these stands are the characteristics of the tropical dry regions.

Relative frequency is another parameter for studying the nature of distribution of a species in a plant community. It expresses the relative distribution of a species amongst rest of the others occupying the area.

Density

Density is an expression of the numerical strength of a species. It was maximum for every species during the growing period, followed by winter and reached upto minimum in summer season except few variations on both the stands (Table III 5a,b) which can easily be explained. Out of the total density (893.34/m^2) during the growth period, a major contribution was made by perennial grasses, such as Dichanthium annulatum (528.40/m^2) and Desmotachya bipinnata (45.20/m^2). Aristida adscensionis, Paspalidium flavidum and Eragrostris gangetica; the annual grasses, constituted 41.84, 28.32 and 27.44/m^2 respectively. Likely, amongst the nongrasses, Cassia tora and Eletraria crenata shared 20.16 and 17.44/m^2 respectively; and thereby, showed their significant contribution towards

Table III 5a: Protected stand

Species	Frequency (%)	Density /m^2	Abundance	Basal cover cm^2/m^2	Percentage: Relative frequency	Percentage: Relative density	Percentage: Relative basal cover	I.V.I.
Rainy season								
Dichanthium annulatum	98	528.40	539.16	36.98	8.57	59.15	23.14	90.86
Desmostachya bipinnata	28	45.20	161.40	5.67	2.45	5.06	3.55	11.06
Cassia tora	76	20.16	26.52	3.16	6.65	2.26	1.98	10.89
Aristida adscensionis	42	41.84	99.60	0.73	3.67	4.68	1.22	9.57
Justicea simplex	60	15.68	26.12	0.49	5.25	1.75	0.81	7.81
Paspalidium flavidum	62	28.32	45.64	0.79	5.42	0.32	1.33	7.07
Elytraria crenata	48	17.44	36.32	0.21	4.20	1.99	0.35	6.54
Eragrostris gangetica	24	27.44	114.32	0.48	2.10	3.07	0.80	5.97
Manisuris granularis	50	10.00	28.00	0.08	4.37	1.12	0.13	5.62
Brachiaria reptans	40	10.96	37.40	0.19	3.50	1.23	0.32	5.05
Orthosiphon pallidus	40	3.20	8.0	0.16	3.50	0.36	0.28	4.14
Boerhavia diffusa	38	2.72	7.12	0.19	3.32	0.30	0.32	3.94
Triumfetta rhomboidea	30	1.76	5.84	0.29	2.62	0.20	0.48	3.30
Digitaria marginata	22	7.12	32.36	0.05	1.92	0.80	0.08	2.80
Minor species	485	133.12	1234.96	10.33	42.43	14.90	17.28	74.61
Total		893.34		59.80				249.23
Winter season								
Dichanthium annulatum	76	429.28	564.84	30.39	16.24	71.53	64.34	152.11
Fimbristylis junciformis	32	29.20	91.24	5.66	6.84	4.86	11.91	23.61
Justicea simplex	60	21.60	36.00	0.66	12.82	3.60	1.40	17.82
Iseilema laxum	22	25.04	113.80	0.97	4.70	4.18	2.05	10.93
Orthosiphon pallidus	30	3.60	12.00	0.18	6.41	0.60	0.38	7.39
Convolvulus pleuricaulis	22	2.48	11.24	0.61	4.70	0.41	1.29	6.40
Evolvulus alsinoides	22	2.64	12.00	0.03	4.70	0.44	0.06	5.20
Minor species	204	86.26	813.64	8.73	43.59	1.04	18.49	63.12
Total		600.10		47.23				286.58
Summer season								
Dichanthium annulatum	96	168.00	175.00	11.76	36.92	78.18	66.87	181.97
Fimbristylis junciformis	28	15.12	54.00	2.94	10.79	7.04	16.72	34.55
Justicea simplex	26	4.64	17.84	0.14	10.00	2.16	0.82	12.98
Minor species	110	27.12	309.56	2.74	42.31	12.62	15.59	70.52
Total		214.88		17.58				300.02

I.V.I. = Importance value index

Table III 5b: Grazed stand

Species	Frequency (%)	Density /m^2	Abundance	Basal cover cm^2/m^2	Percentage			I.V.I.
					Relative frequency	Relative density	Relative basal cover	
Rainy season								
Dichanthium annulatum	60	41.52	69.20	2.91	5.65	5.42	6.82	17.89
Cassia tora	98	115.92	118.28	18.20	9.24	15.14	42.63	67.01
Desmostachya bipinnata	46	29.84	64.80	3.75	4.33	3.90	8.78	17.01
Eragrostris gangetica	50	119.92	239.60	2.10	4.71	15.66	4.92	25.29
Justicea simplex	62	43.68	70.44	1.37	5.84	5.70	3.21	14.75
Sporobolus diander	38	69.92	184.00	0.54	3.58	9.13	1.28	13.99
Echinochloa colonum	50	35.68	71.36	1.74	4.71	4.66	4.08	13.45
Bonnaya brachiata	42	23.44	55.60	0.41	3.96	3.06	0.96	7.98
Desmodium triflorum	36	13.92	38.40	0.43	3.39	1.82	1.01	6.22
Dactyloctenium aegyptium	34	4.56	13.40	0.05	3.20	0.59	0.13	3.92
Corchorus acutangularis	26	1.68	6.40	0.26	2.45	0.22	0.62	3.29
Cyperus kyllinga	24	2.88	12.00	0.23	2.26	0.38	0.53	3.17
Murdania vaginatum	22	6.08	27.60	0.11	2.07	0.79	0.25	3.11
Lindernia crustacea	26	3.20	12.28	0.06	2.45	0.42	0.13	3.00
Minor species	447	253.60	1581.68	10.53	37.42	29.80	23.01	90.23
Total		765.84		42.69				290.31
Winter season								
Rungia repens	80	36.56	4.56	1.13	16.00	27.03	10.07	53.10
Desmostachya bipinnata	46	18.32	39.60	2.30	9.20	13.94	20.44	43.58
Dichanthium annulatum	44	24.80	56.00	1.74	8.80	18.33	15.43	42.56
Periostrophy bicalioulata	40	3.04	7.60	1.89	8.00	2.25	16.77	27.02
Iseilema laxum	38	15.36	40.40	0.59	7.60	11.39	5.27	24.26
Desmodium triflorum	52	11.52	22.12	0.36	10.40	8.51	3.17	22.08
Blumea oxyodonta	36	4.56	12.64	1.03	7.20	3.37	9.15	19.72
Convolvulus pleuricaulis	38	2.72	7.12	0.27	7.60	2.01	2.36	11.97
Alysicarpus monilifer	30	3.36	11.20	0.16	6.00	2.48	1.46	9.94
Evolvulus alsinoides	22	2.48	11.24	0.02	4.40	1.83	0.18	6.41
Minor species	74	12.56	118.80	1.77	14.80	9.28	15.70	39.78
Total		135.28		11.24				300.42
Summer Season								
Dichanthium annulatum	76	34.32	45.12	2.40	26.57	49.44	43.01	119.02
Desmostachya bipinnata	36	12.00	33.32	1.50	12.99	17.46	28.88	59.33
Rungia repens	38	4.40	10.52	0.03	13.29	6.40	0.48	20.17
Desmodium triflorum	26	3.20	12.28	0.10	9.09	4.66	1.77	15.22
Minor species	110	14.80	136.20	1.55	38.46	21.54	27.85	87.85
Total		68.72		5.58				301.89

I.V.I. = Importance value index

the total density of the stand. During winter season, higher density was recorded for D. annulatum ($429.28/m^2$); Fimbristylis junciformis ($29.20/m^2$); Iselema laxum ($25.04/m^2$) and a non-grass Justicea simplex ($21.60/m^2$). While in summer season, D. annulatum ($168.0/m^2$); F. junciformis ($15.12/m^2$) and J. simplex ($4.64/m^2$) were found to be the main contributors towards total density ($214.88/m^2$) of the stand. Thus it is quite evident that D. annulatum showed its maximum numerical strength on protected stand in all the three seasons.

On the other hand, the maximum density of annual grasses, such as E. gangetica ($119.92/m^2$); Sporobolus diander ($69.92/m^2$); along with some nongrasses e.g. C. tora ($115.92/m^2$) and J. simplex ($43.68/m^2$) was recorded in the vegetation during growth period on grazed stand.

Such differences in the numerical strength of various species on two stands studied were likely to be explained that the density of D. annulatum ($41.52/m^2$) D. bipinnata ($29.84/m^2$) remained suppressed due to heavy grazing in the monsoon period.

During winter and summer seasons, due to lower grazing pressure, D. annulatum, D. bipinnata have enjoyed a fair chance to become dominant and shared maximum density i.e. 24.80 and $18.32/m^2$ respectively to the total density of $135.28/m^2$ in winter; and 34.32 and $12.0/m^2$ respectively to the total density of $68.72/m^2$ in summer seasons. Amongst the nongrasses, Rungia repens and Desmodium triflorum were

quite distinct from their density point of view i.e. 36.56 and 11.52/m^2 in winter and 4.40 and 3.2/m^2 respectively in summer seasons.

Therefore, except in monsoon period, when the vegetation was dominated by annual grasses and nongrasses, D. annulatum and D. bipinnata remained dominant in the rest of the period of a year.

Relative density is another parameter of the numerical strength of a species in relation to total density of all the species occupying an area.

Basal cover

The basal area of a species is regarded as an index of dominance. It was observed that the maximum value of basal cover of D. annulatum was 36.98, 30.39 and 11.76 cm^2/m^2 in rainy, winter and summer seasons respectively, which clearly indicate towards its dominant position in the protected stand. The other codominants were those of D. bipinnata and F. junciformis.

Similarly on grazed stand, the basal cover of D. annulatum and D. bipinnata was maximum in winter and summer seasons, except in rainy season when the maximum basal cover was attained by C. tora (18. 20 cm^2/m^2)and D. bipinnata (3. 75 cm^2/m^2). It indicates towards the regeneration of new tillers from these two perennial grasses after heavy grazing during best period of growth in this stand.

Relative basal area (R.B.) is another parameter of coverage value of a species in relation to the sum of the coverage of all the species occupying the area.

<u>Importance Value Index</u> (IVI)

Curtis and McIntosh (1950) have pointed out that single characteristic of vegetation can not form a dependable parameter for the characterization and composition of vegetation. They, therefore, used I.V.I. by consolidating the relative values of three quantitative characteristics of the vegetation and suggested that I.V.I. gives better information about the dominance and ecological success of a species.

The I.V.I. of all species, except the species grouped under frequency class A have been worked out during all the three seasons on both the stands. The species belonging to class <u>A</u> have been considered as species of minor importance and therefore their separate values of R.F., R.D. and R.B. are not presented in Table III 5a,b). However, their I.V.I. were calculated separately, summed up and presented as the I.V.I. of minor species.

<u>D. annulatum</u>, a dominant perennial grass, showed its maximum I.V.I. values i.e. 90.86, 152.11, 181.97 (Table III 5a) in rainy, winter and summer seasons respectively for protected stand.

In contrast to this on grazed stand C. tora was found to be the most important species during rainy season (Table III 5b) with a I.V.I. value of 67.01. However, D. annulatum was conspicuous by its presence in winter and summer seasons showing its higher I.V.I. values 42.56 and 119.02 respectively than rest of the other species, except D. bipinnata with a value of 43.58 and 59.33 in winter and summer seasons respectively.

DISCUSSION

Results of phytosociological studies reveal that the species diversity was greater during rainy season on both the stands and they were quite dissimilar in respect to their species composition. Most prominant seasonal changes were also recorded on the two stands studied.

A great species diversity during rainy season may be attributed to the congenial environmental conditions for the growth of most of the producers. Soil moisture appears to have some direct effects on diversity of the vegetation. Trivedi (1976) has advocated the importance of soil moisture in the development of herbaceous vegetation.

It is evident from the list of species occurring on both the stands, that protected stand had greater variety of species in comparison to grazed stand. It may be explained on the basis of the fact that protection of protected stand against grazing by large vertebrate herbivores had given fair chances for emergence and establishment of variety of

species which were unable to do so under grazing pressure on grazed stand. However, the vigorous growth of perennial grasses such as D. annulatum, D. bipinnata and F. junciformis suppressed the growth and development of various legumes and other forbs on protected stand in their initial developmental stages, during monsoon period and therefore they remained suppressed throughout the year, probably due to interspecific competition. While on grazed stand, due to grazing, the palatable perennial grasses including few forbs showed their suppressed growth and hence this stand became dominated by C. tora alongwith some annual grasses such as S. diander, E. gangetica and P. flavidum. It may be due to the fact that they remained more or less untouched by grazing animals during rainy season because of the availability of other palatable forage in plenty e.g. D. annulatum, A. adscensionis, A. monilifer and D. triflorum. With the change in climatic conditions in winter most of the annual species perished mainly due to their short life span, poor establishment capacity and lack of competitive power.

The herbaceous flora in general followed the decreasing order of Raunkiaer's Life Forms as Therophytes, Hemicryptophytes, Cryptophytes and Chaemophytes. The preponderance of Therophytes resulted from a strong periodicity in climatic and biotic operations/ disturbances. The top rank of Therophytes in Indian grasslands has also been reported by Bharucha and Dave (1944). The higher number of Therophytes

have been considered due to biotic operations and overgrazing in the area (Cain, 1950; Pandeya, 1953). However, it seems that not only the biotic disturbances which are responsible for enhancement of Therophyte populations but the normal periodicity and efficiency of monsoon results in the prolific growth of seasonal (i.e. rainy) annuals which may also increase the percentage of Therophytes as well. The short life span of Therophytes from their sprouting to flowering, fruiting and seed setting is completed during winter months. These plants over off the unfavourable hot and dry period by their seeds. They behave as 'Escapes' and 'Opportunists' due to their reappearance in late winter and/or early summer if there are rains and congenial temperatures.

The plants belonging to Cryptophyte and Hemicryptophyte groups were able to with-stand the grazing pressure because of their buds which remained hidden in soil subsurface position.

Most prominant effects of grazing were observed on frequency, density and stratification of various species. The herbage removal resulted (Table III 5b) in the increment of all these parameters in species like: C. tora, E. gangetica, J. simplex and E. colonum. Whereas D. annulatum and D. bipinnata were found to be affected adversely. Seasonwise fluctuations were recorded in the density of various species, however, it attained its maxima during rainy season. Increased density of certain rainy season annuals accounts

due to the availability of more bare space, as a result of grazing on grazed stand. On the other hand protection on protected stand supported domination of perennial vegetation throughout the year. The higher density of various species in rainy season is in conformity with Misra (1973) and many others.

Variations in the I.V.I. of various species are presented in Table III 5a,b. The I.V.I. of different species varied from season to season. High values of some species during winter and summer months may be ascribed to the absence of other associates in the community during this unfavourable period of the year. Misra (1973, Ujjain), Asthana (1974, Gorakhpur) and Trivedi (1976, Jhansi) recorded similar fluctuations in I.V.I. of dominant species in the grasslands studied by them.

The comparative variations in positions of various species according to their I.V.I. reflects upon their relative ecological success throughout the year. On protected stand, D. annulatum had its maximum I.V.I. in all the seasons, while on grazed stand C. tora attained the maximum I.V.I. (67.01) in rainy season;and therefore, D. annulatum and D. bipinnata became prominant for rest of the period of a year in respect to their I.V.I. values. However, exceptionally R. repens had higher I.V.I. during winter season. It may be explained because of disappearance of annuals after completion of their life cycle and the regeneration of new tillers in former two species after grazing.

Since the D. annulatum contributed relatively higher phytomass in protected stand -probably due to its frequent distribution, hence it may be considered as a dominant species of the protected stand, while D. annulatum alongwith the D. bipinnata have been recorded as dominant species on grazed stand due to their greater I.V.I. and phytomass contribution.

From the statistical analysis the relationship of various parameters are worked out. Density of the vegetation is positively related to Basal cover with correlation coefficient $r = 0.98$, $P < .05$ and 0.99, $P < .001$ and Density is further directly related to Diversity Index with $r = 0.98$, $P < .05$ and 0.99, $P < .001$ for the two stands respectively (Fig. 4a,b). Similar relationships were observed by Gupta (1978).

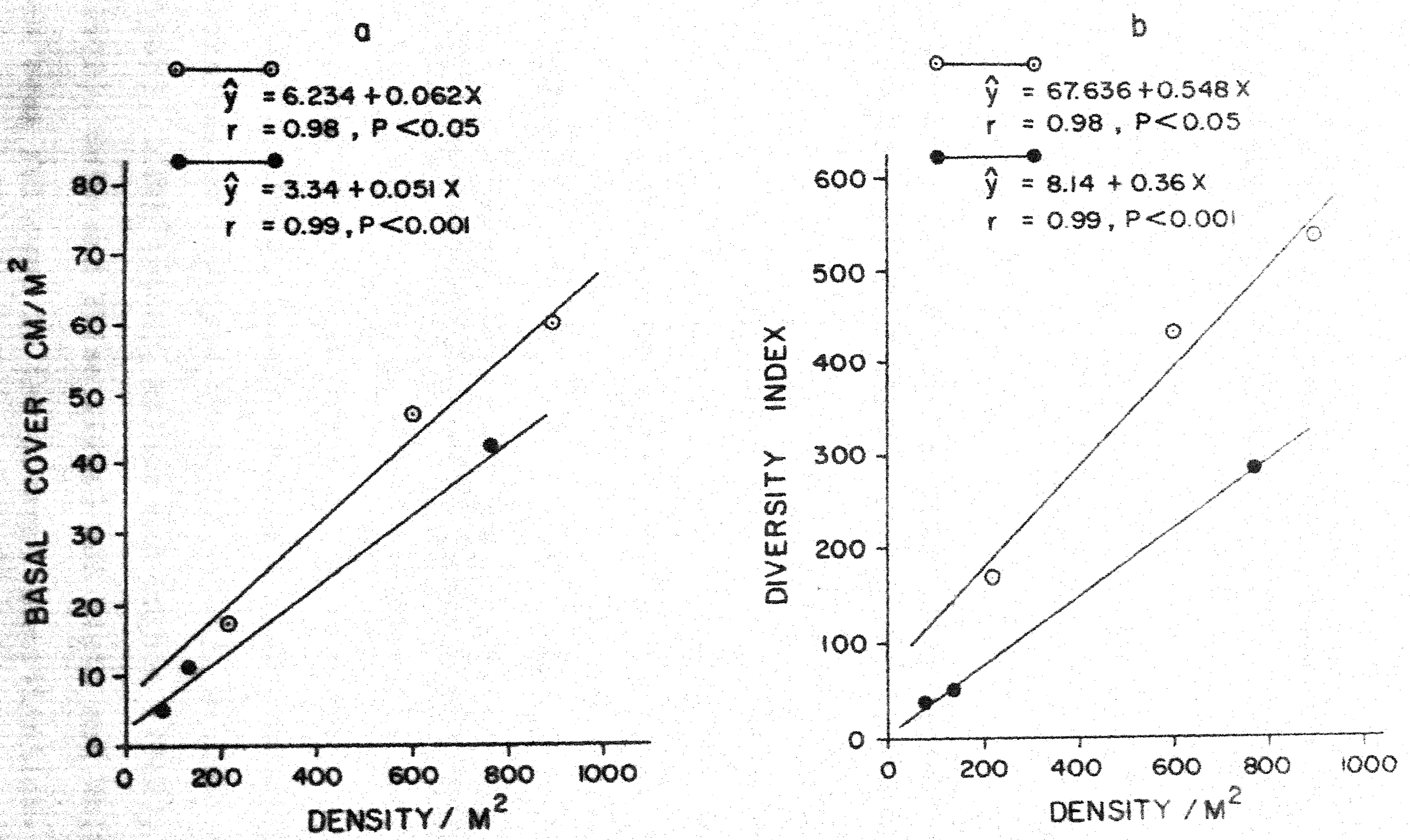


FIG. 4 – RELATIONSHIPS BETWEEN VARIOUS STRUCTURAL PARAMETERS IN ⊙——⊙ PROTECTED STAND, ●——● GRAZED STAND

CHAPTER IV

PHYTOMASS AND PHOTOSYNTHETIC STRUCTURE

SECTION A

PHYTOMASS

The total weight of plant dry matter present in ecosystem at any time accounts for its phytomass. Estimations of phytomass are essential in determining the status and flux of biological material in ecosystems, and necessary to understand their dynamics (Anderson, 1971). Standing crop phytomass gives only the static picture of an ecosystem, providing an estimate of the organic matter that is present per unit area at a particular time. Dynamic picture of an ecosystem can be obtained by estimating the periodical changes in standing phytomass at short intervals over a period of time.

METHODS

Standing crop has been estimated by 'short term harvest method' (Odum, 1960) in which variation in phytomass is estimated at short intervals. In order to get shoot and root intact of the different species of the community, the core technique as employed by Raman (1960), Dahlman and Kucera (1965), Lieth (1968), Milner and Hughes (1968), Daubenmire (1972), Wein and Bliss (1974) and Lieth and Whittakar (1975) has been followed in the present investigation. First sampling was made in the last week of June (when the 1st

grass growth starts) to get a base for the study of the phytomass for one complete year i.e. June 1977 to June 1978.

The standing crop phytomass was sampled on 25 x 25 cm plots upto a depth of 30 cm (Golley, 1965) from different sampling points distributed homogeneously in the study stands. Three monoliths were dug up. Excavated monoliths were placed in wire cages to facilitate transport and washing. Monoliths were washed carefully in water to get soil free underground parts of the plants. Aboveground parts of Grasses, Legumes and Forbs and underground parts of the same were separated. Legumes and Forbs members of the plant community were designated as non-grasses. The aboveground parts have been further separated into Live phytomass (green/non-green) and Standing Dead. Litter phytomass was collected at the time of harvest. All the parts were oven dried (at a temperature of 70°C) and calculated in terms of gram/square metre/month.

Phytomass studies

Phytomass has been calculated separately for grasses and non-grasses compartments and for the community as a whole and values have been tabulated in Tables IV 1a,b + 2a.b. for both the stands.

Standing Live Phytomass

Data presented in the Table IV 2a for protected stand revealed that total standing live phytomass varied considerably through different months. A peak value of 1235.40 g/m^2 was

Table IV 1a: Monthly phytomass values of different components in the two compartments (g/m^2)

(Protected stand)

Months	Grass (Compartment A)					Nongrass (Compartment B)					Total phytomass
	St. Live	St. Dead	Above ground total	Under ground	Total	St. Live	St. Dead	Above ground total	Under ground	Total	
June	77.40	200.10	277.50	248.00	525.50	3.10	2.15	5.25	1.20	6.45	531.95
July	279.90	110.20	390.10	298.32	688.42	11.88	-	11.88	3.82	15.70	704.12
August	752.31	80.79	833.10	391.85	1224.95	26.80	-	26.80	13.74	40.54	1265.49
September	910.63	200.20	1110.83	505.20	1616.03	47.84	5.37	53.21	20.86	74.07	1690.10
October	1145.69	335.05	1480.74	616.80	2097.54	89.71	20.16	109.87	28.63	138.50	2236.04
November	895.83	521.64	1417.47	752.38	2169.85	50.44	30.16	80.60	37.74	118.34	2288.19
December	410.62	603.72	1014.34	670.12	1684.46	10.76	24.48	35.24	15.12	50.36	1734.82
January	543.63	538.04	1081.67	729.76	1811.43	16.90	11.93	28.83	20.69	49.52	1860.95
February	457.68	597.40	1055.08	570.60	1625.68	6.74	3.44	10.18	9.45	19.63	1645.31
March	325.44	374.68	700.12	454.76	1154.88	3.48	2.00	5.48	4.24	9.72	1164.60
April	201.00	215.14	416.14	322.61	738.75	0.57	0.86	1.43	2.74	4.17	742.92
May	85.10	224.48	309.58	309.00	614.58	0.20	0.52	0.72	1.50	1.22	615.80
June	136.47	179.02	315.49	333.45	648.94	4.47	1.10	5.57	1.90	7.47	656.41

Table IV 1b: Monthly phytomass values of different component in the two compartments (g/m^2)
(Grazed stand)

Months	Grass (Compartment A)					Nongrass (Compartment B)					Total phyto-mass
	St. Live	St. Dead	Above ground total	Under ground	Total	St. Live	St. Dead	Above ground total	Under ground	Total	
June	35.08	14.05	49.13	30.22	79.35	5.25	-	5.25	2.50	7.75	87.10
July	88.57	4.16	92.73	43.36	136.09	38.26	-	38.26	12.34	50.60	186.69
August	122.39	12.76	135.15	104.40	239.55	167.67	2.08	169.75	29.13	198.88	438.43
September	77.08	31.31	108.39	173.04	281.43	284.56	10.08	294.64	60.30	354.94	636.37
October	42.24	28.32	70.56	221.81	292.37	231.44	32.45	263.89	96.55	360.44	652.81
November	69.20	22.21	91.41	184.97	276.38	75.39	84.56	159.95	58.27	218.22	494.60
December	28.97	39.60	68.57	159.23	227.80	10.75	30.08	40.83	37.57	78.40	306.20
January	57.32	27.36	84.68	190.16	274.84	16.36	14.87	31.23	39.13	70.36	345.20
February	48.13	25.59	73.72	208.88	282.60	9.20	2.30	11.50	23.04	34.54	317.14
March	25.40	30.23	55.63	169.03	224.66	5.83	2.55	8.38	9.14	17.52	240.18
April	19.79	19.32	39.11	102.67	141.78	2.51	1.02	3.53	4.68	8.21	149.99
May	10.27	12.31	22.58	79.82	102.40	0.80	-	0.80	0.64	1.44	103.84
June	39.59	10.85	50.44	50.38	100.82	7.42	-	7.42	6.79	14.21	126.03

Table IV 2a: Monthly phytomass values of different components.
(g/m^2) (Protected stand)

Months	St. Live	St. Dead	Aboveground Total	Underground	Total Phytomass
June	80.50	202.25	282.75	249.20	531.95
July	291.78	110.20	401.98	302.14	704.12
August	779.11	80.79	859.90	405.59	1265.49
September	958.47	205.57	1164.04	526.06	1690.10
October	1235.40	355.21	1590.61	645.43	2236.04
November	946.27	551.80	1498.07	790.12	2288.19
December	421.38	628.20	1049.58	685.24	1734.82
January	560.53	549.97	1110.50	750.45	1860.95
February	464.42	600.84	1065.26	580.05	1645.31
March	328.92	376.68	705.60	459.00	1164.60
April	201.57	216.00	417.57	325.35	742.92
May	85.30	225.00	310.30	310.50	620.80
June	140.94	180.12	321.06	335.35	656.41

Table IV 2b: Monthly phytomass values of different components (g/m^2) (Grazed stand)

Months	St. Live	St. Dead	Above ground total	Under ground	Total phytomass
June	40.33	14.05	54.38	32.72	87.10
July	126.83	4.16	130.99	55.70	186.69
August	290.06	14.84	304.90	133.53	438.43
September	361.64	41.39	403.03	233.34	636.37
October	273.68	60.77	334.45	318.36	652.81
November	144.59	106.77	251.36	243.24	494.60
December	39.72	69.68	109.40	196.80	306.20
January	73.68	42.23	115.91	229.29	345.20
February	57.33	27.89	85.22	231.92	317.14
March	31.23	30.78	62.01	178.17	240.18
April	22.30	20.34	42.64	107.35	149.99
May	11.07	12.31	23.38	80.46	103.84
June	47.01	21.85	68.86	57.17	126.03

obtained in October and then declined to a minimum of 85.30 g/m^2 in May, with a slight rise in the phytomass in January with a value of 560.53 g/m^2.

The two compartments grasses and non-grasses showed a definite variation trend in phytomass value throughout the year. Grasses (Compartment A) reached to their maximum value of 1145.69 g/m^2 in October, while non-grasses (Compartment B) in the same month with a value of 89.71 g/m^2 (Table IV 1a). The phytomass values of compartment A showed a gradual declining trend while the values of compartment B declined sharply. Both the compartments showed a minor increase in their phytomass values in the month of January. Grasses shared a major portion of the total standing live phytomass as evident in Table IV 3. They contributed maximum share of 99.7% in the month of April and minimum 92.7% in the month of October. Conversely the non-grasses contributed maximum 7.3% in October and minimum 0.3% in April/May.

Similarly on grazed stand, perusal of the Table IV 2b revealed that a peak value of 361.64 g/m^2 was obtained in September and then declined to its minimum of 11.07 g/m^2 in May, except a mini peak in January with a value of 73.68 g/m^2.

Considering the two compartments of the grazed stand separately, grasses showed maximum amount(122.39 g/m^2)in August, while non-grasses(284.56 g/m^2)in September (Table IV 1b) Because of heavy grazing phytomass value in the remaining period of the year showed a decreasing trend.

Table IV 3: Percentage contribution of the two compartments in the total standing crop of different components

Months	Protected stand						Grazed stand					
	St. Live		St. Dead		Underground		St. Live		St. Dead		Underground	
	A	B	A	B	A	B	A	B	A	B	A	B
June	96.1	3.9	98.9	1.1	99.5	0.5	86.9	13.1	100	-	92.3	7.7
July	95.9	4.1	100	0	98.6	1.4	69.8	30.2	100	-	77.8	22.2
August	96.5	3.5	100	0	96.5	3.5	42.1	57.9	85.9	14.1	78.1	21.9
September	95.0	5.0	98.3	1.7	96.0	4.0	21.3	78.7	75.6	24.4	74.1	25.9
October	92.7	7.3	94.3	5.7	95.5	4.5	15.4	84.6	46.6	53.4	69.6	30.4
November	94.6	5.4	94.5	5.5	95.2	4.8	47.8	52.2	20.8	79.2	76.0	24.0
December	97.4	3.6	96.1	3.9	97.7	2.3	72.9	27.1	56.8	43.2	80.9	19.1
January	96.9	3.1	97.8	2.2	97.2	2.8	77.7	22.3	64.7	35.3	82.9	17.1
February	98.5	1.6	99.4	0.6	98.3	1.7	83.9	16.1	91.7	8.3	90.0	10.0
March	98.9	1.1	99.4	0.6	99.0	1.0	81.3	19.7	98.2	1.8	94.8	5.2
April	99.7	0.3	99.6	0.4	99.1	0.9	88.7	11.3	94.9	5.1	95.6	4.4
May	99.7	0.3	99.7	0.3	99.8	0.2	92.7	7.3	100	-	99.2	0.8
June	96.8	3.2	99.3	0.7	99.4	0.6	84.2	15.8	100	-	88.0	12.0

The grass compartment showed two more fluxes of growth, one in November(69.20 g/m^2), reflecting thereby the new growth during the rest period after grazing in the monsoon period. Another rise was in January(57.32 g/m^2),which indicated new growth due to winter showers. But non-grass compartment had only one mini peak in January.

The percentage contribution of the two compartments to the total standing live phytomass fluctuated throughout as a result of grazing. During initial growth stage share of grasses was more but in August, September, October and November the share of non-grasses was more (Table IV 3), with a maximum of 84.6% in October. In the rest of the year grasses contribution was more throughout with a maximum of 92.7% in May.

Standing Dead Phytomass

As evident from Table IV 2? the total standing dead phytomass of protected stand showed a considerable variation at different sampling intervals. Total standing dead phytomass was maximum being 628.20 g/m^2 in December and minimum being 80.79 g/m^2 in August. In February a second peak value of 600.84 g/m^2 was recorded. Thus the standing dead phytomass value was lower in rainy season, increased to its maximum value in winter months and again declined during summer.

The trend of fluctuation of standing dead phytomass of the two compartments was almost similar to that of total standing dead phytomass. The grasses showed maximum value of

603.72 g/m^2 in December while non-grasses in November with a value of 30.16 g/m^2 (Table IV 1a).

The percentage contribution of grasses was high in standing dead phytomass, as was obtained for live phytomass, with the maximum value (99.7%) in May and minimum (94.3%) in October, but non-grasses percentage was found high (5.7%) in October (Table IV 3).

Similarly on grazed stand, the total standing dead phytomass increased gradually from July with a value of 4.16 g/m^2 to November with a maximum value of 106.77 g/m^2 and then again a declining trend was observed upto May (Table IV 2b). The two compartments revealed a similar trend to that of total standing dead phytomass, with a maximum value in winter. For grass compartment 39.60 g/m^2 was observed in December, while non-grass showed maximum value 84.56 g/m^2 in November (Table 1b). The minimum value was observed in rainy season. The percentage contribution of compartment A was high throughout except in October and November, when compartment B recorded maximum contribution (Table IV 3).

Aboveground standing phytomass

The aboveground standing phytomass changed considerably from month to month. On protected stand the phytomass of the grass compartment showed an increasing trend with 390.10 g/m^2 in July to a maximum of 1480.74 g/m^2 in October and then declined to a minimum value of 309.58 g/m^2 in May, with only a minor rise in the value in the month of January (Table IV 1a).

Similarly, in the nongrass compartment, the aboveground phytomass increased from 11.88 g/m^2 in July with a maximum of 109.87 g/m^2 in October and then declined sharply to a value of 0.72 g/m^2 in May.

Considering the total aboveground standing phytomass of the community (Protected stand), the values showed an increasing trend from 401.98 g/m^2 in July to a maximum of 1590.61 g/m^2 in October and then gradually declined with a minimum of 310.30 g/m^2 in May (Table IV 2a and Fig. 5). A slight increase in the aboveground phytomass was reported in the month of January with a value of 1110.50 g/m^2, due to winter showers.

On grazed stand, the aboveground phytomass of grass compartment recorded maximum value of 135.15 g/m^2 in August and two mini peaks one in November (91.41 g/m^2) and another (84.68 g/m^2) in January. The minimum value was(22.58 g/m^2) in May (Table IV 1b). While of the non-grass compartment, it increased from 38.26 g/m^2 in July to a maximum of 294.64 g/m^2 in September and then sharply declined till May with a minimum value of 0.80 g/m^2. Considering the community aboveground phytomass, the value increased from 130.99 g/m^2 in July to a maximum of 403.03 g/m^2 in September and then declined to 23.38 g/m^2 till May, with a mini rise(115.91 g/m^2)in January (Table IV 2b and Fig. 5).

Underground phytomass

A perusal of the Table IV 2a (Fig. 5) revealed that the underground phytomass of protected stand increased progressively

from 302.14 g/m^2 in July to a peak value of 790.12 g/m^2 in November and then gradually declined to a minimum value of 310.50 g/m^2 in May, except January with a value of 750.45 g/m^2.

Considering the phytomass value of the two compartments separately, the grasses as well as non-grasses showed the similar trend with their peak values of 752.38 g/m^2 and 37.74 g/m^2 respectively in November and minimum values of 309.00 g/m^2 and 1.50 g/m^2 in May (Table IV 1a). Thus the fluctuations observed in the total underground phytomass of the community was mainly due to grasses, because they shared a major portion of the total underground phytomass. The dominant grasses contributed a maximum percentage of 99.8% in May and minimum 95.2% in November, while nongrasses with a maximum of 4.8% in November and a minimum value 0.2% in May (Table IV 3).

For grazed stand, Table IV 2b (Fig. 5) revealed the similar trend of rise and fall. It increased from July 55.70 g/m^2 to a peak value of 318.36 g/m^2 in October, as compared to November in protected stand and then declined till June, only with a small rise in January and February. The two compartments (Table IV 1b) separately revealed the same result with their maximum values (221.81 g/m^2 and 96.55 g/m^2), in the same month i.e. October, compared to November in protected stand. The grasses contributed maximum share throughout the study period, ranging from 69.6% in October

to 99.2% in May. Reverse to this, the maximum share of non-grass compartment was 30.4% in October, and a lesser value throughout the year (Table IV 3).

Total Phytomass

The total standing crop phytomass changed from month to month. With the onset of monsoon total phytomass gradually increased on protected stand from July onward attaining a peak value of 2288.19 g/m^2 in November, followed by a decrease with a minimum value of 620.80 g/m^2 in May (Fig. 5). There was a slight increase in phytomass value 1860.95 g/m^2 in the month of January, due to winter rains. A major portion of the total phytomass was contributed by grasses, with a maximum of 99.8% in May (Table IV 4).

Compared to protected stand, in grazed stand the peak ? value (652.81 g/m^2) was obtained in October and minimum (103.84 g/m^2) in May (Fig. 5). A mini peak in January (345.20 g/m^2) was also observed in the stand. Similar to protected stand, a major portion of the total phytomass was contributed by grasses with a maximum value of 98.6% in May, except the period September and October, where percentage contribution of nongrasses was more with a maximum of 55.8% in September (Table IV 4).

Underground and Aboveground phytomass ratio (UG/AG)

The underground and aboveground phytomass ratio has been given due importance by Bray *et al*., 1959; Pearson, 1965;

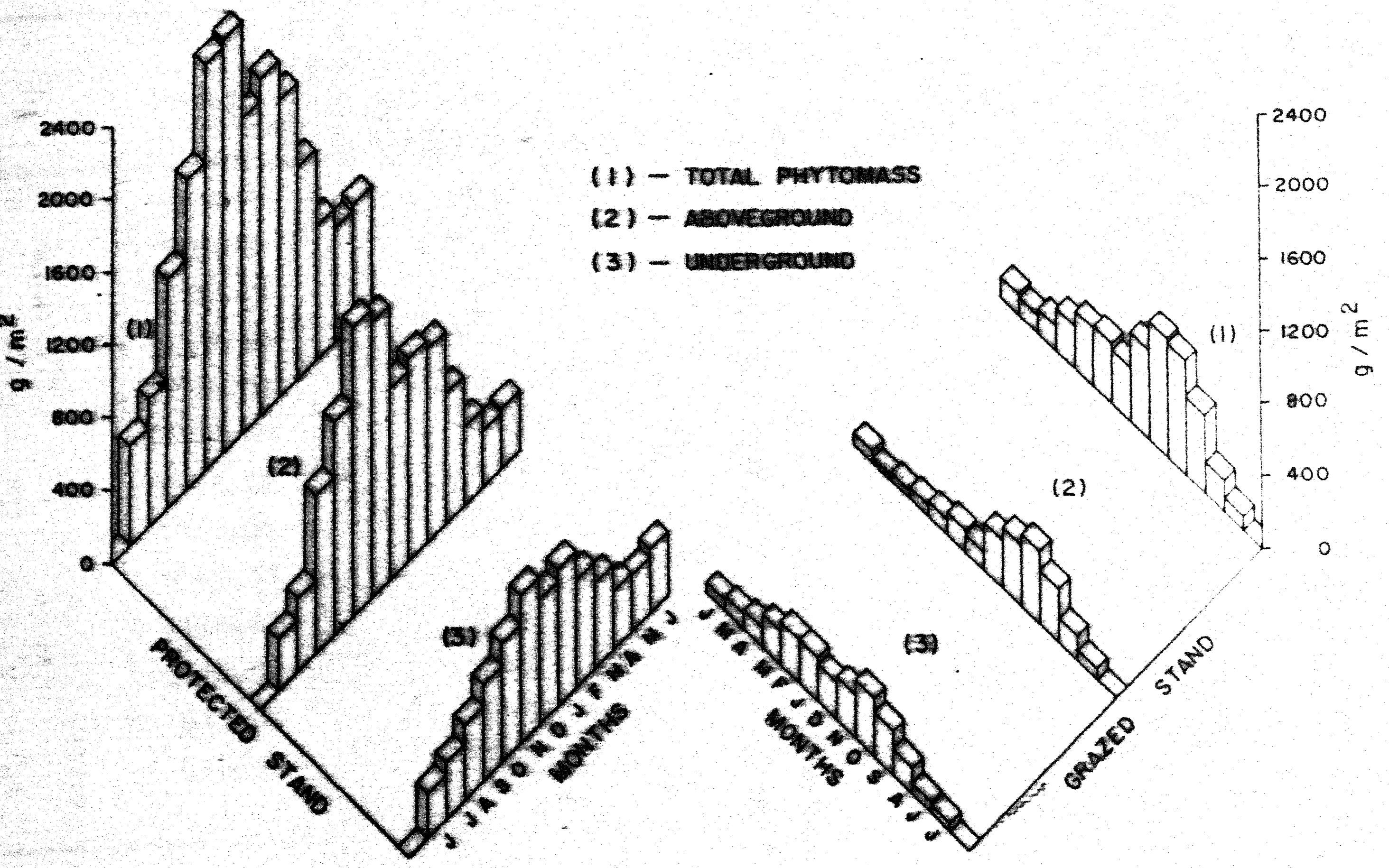


FIG. 5 – MONTHLY VARIATION IN TOTAL PHYTOMASS, ABOVEGROUND AND UNDERGROUND PHYTOMASS (g/m^2), PROTECTED AND GRAZED STAND.

Table IV 4: Percentage contribution of the two compartments in the total phytomass.

Months	Protected stand			Grazed stand		
	Total phytomass	% Contribution A	% Contribution B	Total phytomass	% Contribution A	% Contribution B
June	531.95	98.8	1.2	87.10	91.1	8.9
July	704.12	97.7	2.3	186.69	72.8	27.2
August	1265.49	96.7	3.3	438.43	54.6	45.4
September	1690.10	95.6	4.4	636.37	44.2	55.8
October	2236.04	93.7	6.3	652.81	44.8	55.2
November	2288.19	94.9	5.1	494.60	55.8	44.2
December	1734.82	97.1	2.9	306.20	74.3	25.7
January	1860.95	97.4	2.6	345.20	79.6	20.4
February	1645.31	98.9	1.1	317.14	89.1	10.9
March	1164.60	99.2	0.8	240.18	93.5	6.5
April	742.92	99.5	0.5	149.99	94.5	5.5
May	615.80	99.8	0.2	103.84	98.6	1.4
June	656.41	98.9	1.1	126.03	79.9	20.1

Monk, 1966; Singh, 1968; Jain, 1971; Odum, 1971; Singh and Yadav, 1972; Dittmer, 1973; Naik and Mishra, 1974; Lieth and Whittaker, 1975; Pandeya et al., 1977 and Ronald, 1978.

The parameter of U.G./A.G. phytomass ratio gives an idea of plant behaviour under existing conditions. The maximum ratio was obtained (1.00) in May and June, followed by December, March, April, July and minimum (0.40) in October (Table IV 5 and Fig. 6) on protected stand. While on grazed stand the higher ratio was observed from December to May (1.79 to 3.44) and lower ratio in the monsoon and post monsoon period (0.42 to 0.96).

The minimum ratio clearly indicate a good growth of aboveground phytomass during growth period and maximum ratio is due to higher proportion of organic matter stored in underground phytomass.

Vertical Phytomass

The importance of Vertical distribution of phytomass has been emphasized by Milner and Hughes (1968), Iwaki et al. (1964), Jain (1971) and Singh and Yadav (1972).

Such studies provide information about stratification in a community and effect of different factors operating on it. The stratification studies are of equal importance in above-ground and underground environments.

Vertical distribution of total aboveground and under-ground crop for protected stand was studied for the growth

Table IV 5: Underground/Aboveground ratio (U.G./A.G.)

Months	Protected stand			Grazed stand		
	Aboveground phytomass	Underground phytomass	Ratio	Aboveground phytomass	Underground phytomass	Ratio
June	282.75	249.20	0.87	53.38	32.72	0.60
July	401.98	302.14	0.75	130.99	55.70	0.42
August	859.90	405.59	0.47	304.90	133.53	0.44
September	1164.04	526.06	0.45	403.03	233.34	0.57
October	1590.61	645.43	0.40	334.45	318.36	0.95
November	1498.07	790.12	0.52	251.36	243.24	0.96
December	849.58	685.24	0.80	109.40	196.86	1.79
January	1110.50	750.45	0.67	115.91	229.29	1.97
February	1085.26	580.05	0.53	85.22	231.92	2.72
March	605.60	459.00	0.75	62.01	178.17	2.87
April	417.57	325.35	0.77	42.64	107.35	2.51
May	310.30	310.50	1.00	23.38	80.46	3.44
June	321.06	335.35	1.04	68.86	57.17	0.83

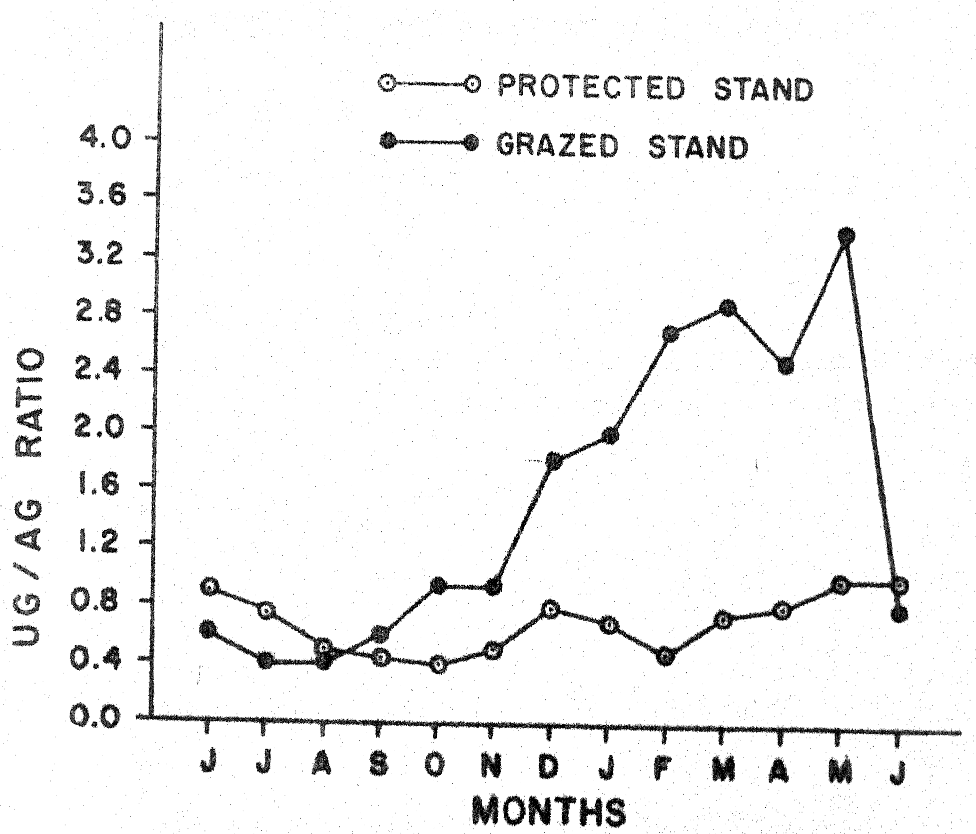


FIG. 6 - MONTHLY VARIATION IN UG/AG RATIO.

period i.e. June, July and October, as presented in Figure 7. The phytomass values are given in Table IV 6.

On examination of this table and Figure, it is clear that with the onset of rainy season, the height of the vegetation increased to a maximum of 150 cm in October and decreased there-after. The height increase was due to the rapid growth of perennial grasses and annual species.

Aboveground phytomass was more concentrated towards the base (0-20 cm) and gave the appearance of an upright pyramid, which showed combined effect of species resulting in some sort of uniformity in distribution and phytomass. The aboveground phytomass in October was projected to a height of 1.50 metres or 150 cm. The phytomass was less in upper layers.

In the case of underground vertical distribution, it showed a maximum phytomass in the top layer of soil i.e. 0 to 10 cm depth. It extended upto 30 cm depth.

DISCUSSION

In grassland communities, changes in the phytomass values at short intervals are attributed to the marked variations in the Ombrothermic and soil conditions to which the phenology of herbaceous species is strongly adapted and adjusted. There are great variations in the standing crop phytomass in different months according to seasonal conditions (Singh,1978).

Misra and Singh (1969) observed on a Varanasi grassland that the best period of growth ranges from end of June to

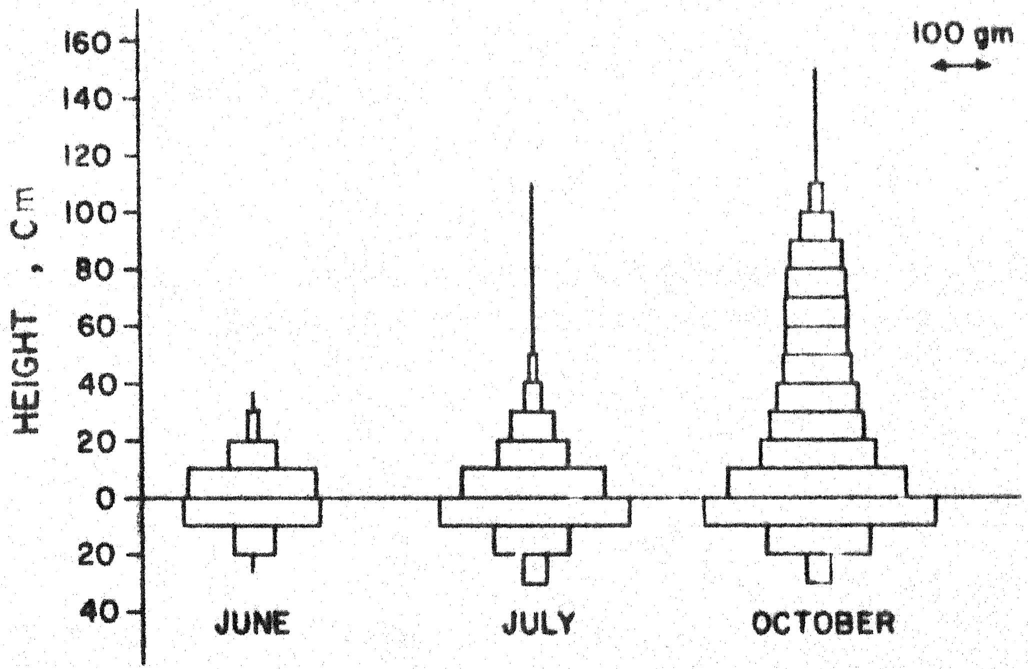


FIG. 7 –

VERTICAL DISTRIBUTION OF PHYTOMASS (AG, UG).

Table IV 6 : Vertical Phytomass (g/m^2)

Height in(cm)	Aboveground			Underground		
	June	Jul.	Oct.	Jun.	Jul.	Oct.
0-10	227.68	244.48	310.01	24.84	333.24	481.05
10-20	81.68	125.76	192.36	68.88	130.14	175.08
20-30	49.92	75.64	161.48		32.05	40.09
30-40	20.16	51.45	140.96			
40-50	-	31.42	131.44			
50-60	-	20.24	127.04			
60-70	-	11.64	111.76			
70-80	-	3.84	92.74			
80-90	-	1.97	56.28			
90-100	-	0.28	21.52			
100-110	-	0.24	7.45			
110-120	-	-	0.96			
120-130	-	-	0.40			
130-140	-	-	0.32			
140-150	-	-	0.16			

September, a period of maximum energy capturing efficiency. Maurya (1970), in a stand dominated by _D. annulatum_, observed that the highest phytomass value was attained in November due to the appearance of most of the photosynthetic tissue from August to October. In the present investigation peak total phytomass (2288.19 g/m^2) was also observed in the month of November on protected stand and (652.81 g/m^2) in October on grazed stand, thereafter the values declined gradually till May with minimum phytomass values of 620.80 and 103.84 g/m^2 respectively, except for a small rise in January 1860.95 and 345.20 g/m^2 respectively. The aboveground share of total phytomass was 1498.07 and 334.45 g/m^2 and underground share was 790.12 and 318.36 g/m^2 respectively for protected and grazed stands.

The fluctuations in the aboveground phytomass can be attributed to the seasonal changes. The rainy season annuals, legumes and grasses on protected stand grow rapidly with the advent of monsoon and, after reaching a peak growth in October, rapidly begin to dry. The decline after October, therefore, may be attributed to the death and shattering of annual species as well as of the seasonal tillers of perennial grasses following maturity. While on grazed stand this decline was observed after September, due to grazing pressure. In January there was a slight increase in the aboveground phytomass which reflects sprouting of new tillers by the perennial species due to winter rains - a common feature in the Indian climatic conditions (Misra, 1959).

It was observed that a major portion of the aboveground phytomass was contributed by dominant grass D. annulatum on protected stand and by D. annulatum, D. bipinnata and Cassia tora on grazed stand. The percent contribution of grasses to aboveground phytomass ranged from 90 to 99% throughout the year on protected stand and 21 to 96% on grazed stand. The increase in contribution made by grasses was concomittent with increase in protection (Jankowska, 1968). The aboveground phytomass is positively related to the total density i.e. tiller/m^2 ($r = 0.87$, NS and $r = 0.95$, $P < .05$ for protected and grazed stand respectively (Fig. 8a). Similarly, it was also found that basal cover of the species is directly related with the phytomass of the community ($r = 0.89$, NS and $r = 0.97$, $P < .05$ for both the stands respectively) Fig. 8b. Both these statistical relations reveals that with an increase in the density and basal cover of the species the phytomass increases, which is in conformity with the observations of Gupta (1978).

According to Bray et al. (1959) changes in the aboveground phytomass influenced the fluctuation in the phytomass of underground parts, which might be due to the translocation of organic material from aboveground parts to underground parts. Under present investigations, underground phytomass increased from July upto November on protected stand, while on grazed stand the values increased from July upto October. Billore (1978) also found higher underground phytomass in rainy

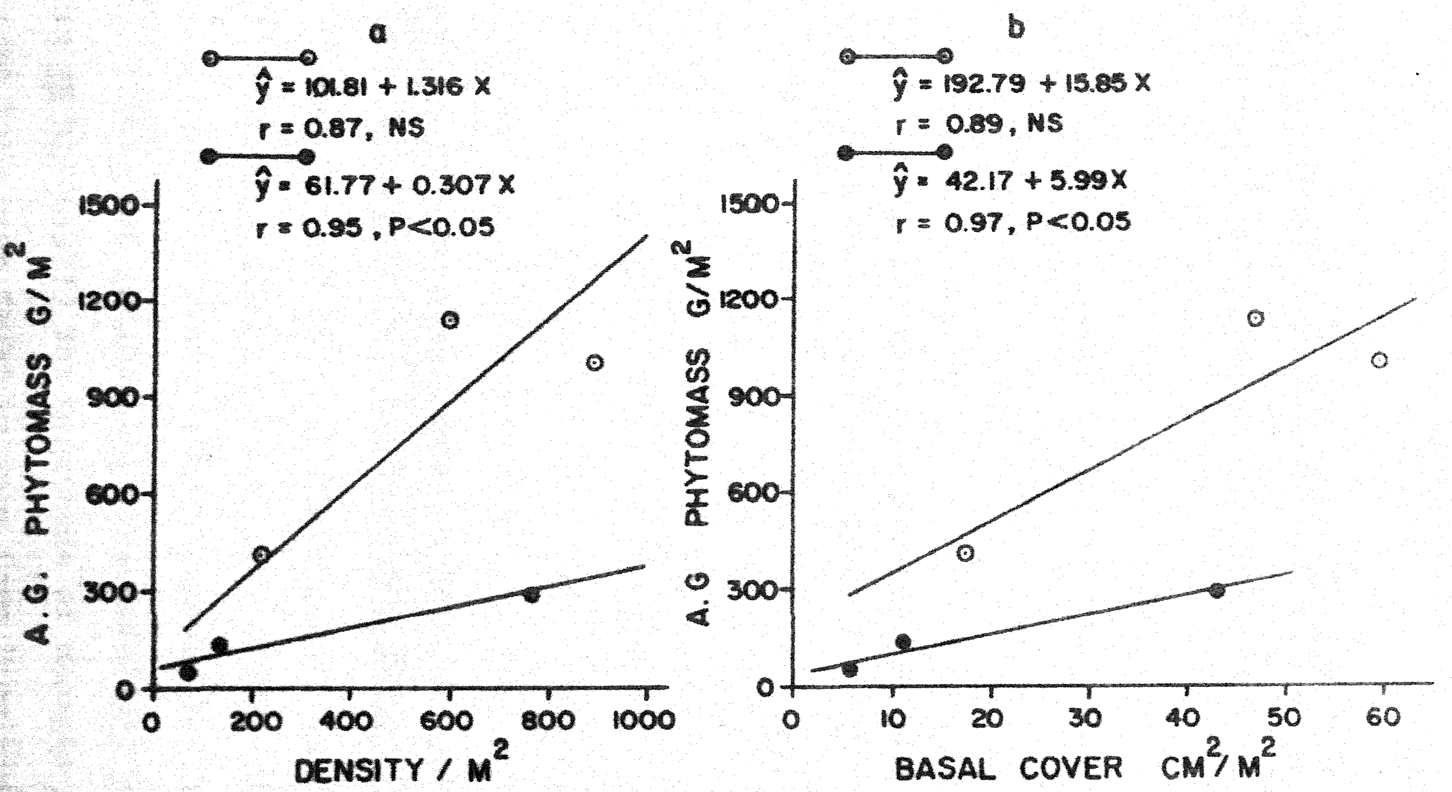


FIG. 8- RELATIONSHIP BETWEEN ABOVEGROUND PHYTOMASS AND STRUCTURAL PARAMETERS IN ⊙——⊙ PROTECTED STAND, ●——● GRAZED STAND.

season than in winter. It may be due to the aaccumulation of organic matter in underground parts from July onwards due to translocation of photosynthates from aboveground parts as also suggested by Bray *et al*. (1959). The decrease in underground phytomass during winter and summer months may be due to cessation of growth and death of the root system under hot and dry condition; or due to disappearance of root system during premonsoon periods, as new tillers appear from March to June at the expense of the root phytomass.

The peaks of aboveground and underground phytomass reached during months i.e. October and November on protected stand and September and October on grazed stand respectively. This observation is in conformity of observations by Ovington *et al*. (1963). These peaks of aboveground and underground phytomass values of the present investigation could be compared with the values of some Indian tropical grasslands (Table IV 9). It is evident from table that the value of aboveground phytomass of protected stand is well within range but higher than that of Singh (1967, Varanasi), Choudhary (1967, Varanasi) and Misra (1973, Ujjain); and lower to Singh (1972b, Varanasi) and Singh and Yadav (1974, Kurukshetra). While the values of grazed stand is lower to that of Trivedi (1976, Jhansi) and Agnihotri (1979, Mandla). According to Pandeya *et al*. (1977) the magnitude of changes in aboveground phytomass have been found to vary from locality to locality, mainly depending on the ecoclimate.

Table IV 9: Peak aboveground and belowground phytomass in some Indian grasslands (g/m^2)

Grassland		Place	A.G.	U.G.	Author	Year
Dichanthium	(Protected)	Varanasi	331.2	583.8	Singh	1967
Dichanthium	(Protected)	Varanasi	571.4	1008.0	Choudhary	1967
Heteropogon	(Protected)	Sagar	1293.3	1789.2	Jain	1971
Heteropogon	(Protected)	Delhi	771.0	330.0	Varshney	1972
Heteropogon	-	Varanasi	3067.7	-	Singh	1972b
Sehima nervosum	-	Ratlam	363.0	873.0	Billore	1973
Dichanthium	-	Ujjain	457.0	925.0	Misra	1973
Cenchrus	(Harvested	Rajkot	221.0	1470.0	Pandeya et al.	1973
Bothriochloa digitaria	(Protected)	Ambikapur	405.0	701.0	Naik and Mishra	1974
Bothriochloa digitaria	(Protected)	Ambikapur	538.2	958.0	Naik and Mishra	1974
Mixed type of	-	Kurukshetra	1974.0	1167.0	Singh and Yadav	1974
Themeda	(Protected)	Jhansi	1221.2	312.0	Gupta	1976
Themeda	(Harvested)	Jhansi	1567.3	506.0	Gupta	1976
Sehima/Heteropogon	-	Jhansi	860.9	767.0	Trivedi	1976
Dichanthium / Iseilema	-	Jhansi	575.8	436.0	Trivedi	1976
Bothriochloa	(Grazed)	Mandla	509.5	927.0	Agnihotri	1979
Bothriochloa	(Ungrazed)	Mandla	1087.1	1496.0	Agnihotri	1979
Dichanthium	(Protected)	Orai	1590.61	790.12	Present study	1980
Dichanthium	(Grazed)	Orai	403.03	318.36	Present study	1980

Similarly, the peak value of underground phytomass of protected stand is higher to the values obtained by Singh (1967, Varanasi), Varshney (1972, Delhi), Naik and Mishra (1974, Ambikapur), Gupta (1976, Jhansi) and Trivedi (1976, Jhansi), but lower to the values of Choudhary (1967, Varanasi), Jain (1971, Sagar), Pandeya et al. (1973, Rajkot), Billore (1973, Ratlam), Misra (1973, Ujjain), Singh and Yadav (1974, Kurukshetra) and Agnihotri (1979, Mandla). While the peak underground phytomass value of grazed stand is lower to that of Gupta (1976, Jhansi), Trivedi (1976, Jhakarwara) and Agnihotri (1979, Mandla).

The U.G./A.G. phytomass ratio was maximum (1.00) in May on protected stand, when the aboveground phytomass could not withstand the hot summer dry months, while it remained high throughout winter and summer on grazed stand, with a maximum (3.44) in May. Maximum U.G./A.G. ratio in summer was also recorded by Naik (1974, Ambikapur), Asthana (1974, Gorakhpur) and Trivedi (1976, Jhansi). The annual average ratio for the protected stand was 0.65 and for the grazed stand it was 1.62. This clearly indicates a higher proportion of phytomass stored in underground parts on grazed stand than that on protected stand. The lower ratio on protected stand may be due to better display of aboveground plant material as a consequence of protection against grazing. This is in conformity with the observation of Billore (1978).

When the annual average ratio is compared with the ratio of other reports (Table IV 10) the ratio of protected stand is almost equal to that of Singh (1967, Varanasi), Jain (1971, Sagar), but lower to Choudhary (1972, Varanasi), Dakwale (1975, Sagar), Trivedi (1976, Jhansi) and Agnihotri (1979, Mandla). Similarly, the U.G./A.G. ratio of grazed stand is higher to the ratio of Gupta (1976, Jhansi) and lower to that of Agnihotri (1979, Mandla). But overall the U.G./A.G. ratio value of both the stands are well within range.

It is not true that there is no growth in total phytomass during the dry months, but it is negligible as compared to respiratory loss and drying; and withering of old growth because of extreme hot and dry conditions.

Vertical distribution of aboveground phytomass gave an appearance of upright pyramid showing combined effect of species resulting in some sort of uniformity in distribution and phytomass, which supports the observation of Singh and Yadav (1972). Sims and Singh (1971), Naik (1973), Gupta (1976), Trivedi (1976) and Billore (1978) observed maximum underground phytomass in the top layer of soil (0-10 cm), the same was found true in this study of vertical distribution of underground phytomass.

Table IV 10: U.G./A.G. Phytomass ratio of various communities

Grassland		Place	Ratio	Author	Year
Dichanthium	—	Varanasi	0.45 - 0.75	Singh	1967
Dichanthium	(Grazed)	Sagar	0.39	Jain	1971
Heteropogon	(Protected)	Sagar	0.50	Jain	1971
Dichanthium	(Protected)	Varanasi	1.09	Choudhary	1972
Mixed type	-	Kurukshetra	0.30	Singh and Yadav	1974
Bothriochloa	(Protected)	Ambikapur	0.79 - 2.28	Naik and Mishra	1974
Bothriochloa	(Protected)	Ambikapur	0.69 - 4.41	Naik and Mishra	1974
Heteropogon	(Protected)	Sagar	1.62	Dakwale	1975
Themeda	(Protected)	Jhansi	0.46	Gupta	1976
Themeda	(Grazed)	Jhansi	0.57	Gupta	1976
Sehima/Heteropogon	-	Jhansi	2.79	Trivedi	1976
Dichanthium - Iseilema	—	Dhakarwara	2.07	Trivedi	1976
Bothriochloa	(Grazed)	Mandla	2.2	Agnihotri	1979
Bothriochloa	(Protected)	Mandla	1.5	Agnihotri	1979
Dichanthium	(Protected)	Orai	0.65	Present study	1980
Dichanthium	(Grazed)	Orai	1.62	Present study	1980

SECTION B

PHOTOSYNTHETIC STRUCTURE

In a plant community, the solar radiation, is trapped and fixed by the photosynthetic green parts of the plant and is stored in the organic matter as chemical energy.

There are two main parts of photosynthetic structure (i) Leaf area - Assimilatory surface for photosynthetic reaction. (ii) Photosynthetic pigments- It is an actual seat of photosynthetic machinery. Thus the photosynthetic area measurement assumes more importance for determining the photosynthetic potentiality. Watson (1958) reported that yield of plants ultimately depends upon the photosynthetic efficiency and extent of photosynthetic surface.

The ratio of leaf area to the ground area has been termed as 'Leaf Area Index' (L.A.I.)(Watson ,1958). Among grasses and herbaceous plants besides the flat spreading leaves which make up photosynthetic surface, leaf sheath, stems and green spikes also contribute significantly to the total photosynthetic area (Thorne, 1966; Eastin and Sullivan, 1969; Dwivedi, 1970; Marwah and Ambastha, 1972). Mall _et al._ (1973) established correlation of leaf area index and chlorophyll content with productivity of _Dichanthium annulatum_ and _Sehima nervosum_ grass communities. Misra and Mall (1975) have worked out the photosynthetic structure in relation to standing crop phytomass of a grassland community at Ujjain.

Ecological significance of the chlorophyll content in biological community lies in the fact that chlorophyll is the most important basis of dry matter production. The chlorophyll of plant communities has been proposed as a parameter characterising the structure and potential photosynthetic productivity of both terrestrial and aquatic ecosystems.

According to Gessner (1949) the chlorophyll content per unit area of land or water tends to be similar in diverse communities, thus strongly suggesting that the content of green pigment in the whole community is more uniform than in individual plant or plant parts. Much emphasis has been laid on the relationship between the chlorophyll content and dry matter production (Bray, 1960). A high level of organic matter production is always a resultant of adequate amount of plant pigments and its functioning most actively in the community(Mall <u>et al</u>., 1973). Therefore, the determination of periodic variability in chlorophyll content per gm plant dry weight and per unit ground area basis is of importance.

In the present investigation L.A.I. and chlorophyll content was estimated for protected stand only.

METHODS

<u>Leaf Area</u>

<u>Sampling</u>

The harvesting technique was employed here again to find out green live phytomass regularly at monthly intervals

from July 1977 to June 1978. The standing crop was harvested in a 10 x 10 cm^2 area above the ground level, kept in an ice box and taken to the laboratory. The green live portions (Leaf and leaf sheaths etc.) were separated carefully for the measurement of area.

Leaf Area Determination

Leaf area of the stand has been calculated by applying the formula of Kemp (1960).

(A) Leaf Area = Lx B x K.

Where L is the maximum length of the leaves, B is the maximum breadth of leaves and K is the Kemp's constant, A = leaf area. K constant was found out by the method described by Kemp (1960). The outline of leaves was traced on a sheet of graph paper and their length and breadth were measured and the total area of the leaf was measured by a planimeter. The constant K was derived by the following formula:-

$L_x B_x K$ = area of leaf (measured by planimeter)

$$K = \frac{\text{Area of leaf (average value)}}{\text{L x B (average value)}}$$

The value of K was found to be 0.89 for grasses and 0.70 for nongrasses. The area of green leaf sheath was calculated by multiplying their length and breadth.

Thus the total leaf area per m^2 was calculated by multiplying their length and breadth with K constant. The

L.A.I. was calculated by dividing the leaf area of all species with the ground area they covered. Average value of leaf area index has been calculated by taking three quadrats from different sampling points. The total green leaves and leaf sheaths were oven dried to get their dry weight and converted on metre square basis.

Photosynthetic Pigment

The harvested plant samples were brought to the laboratory in ice-box to avoid breakdown of pigments. The green phytomass of known weight was taken for chlorophyll estimation. After cutting it to small pieces, the sample was crushed with 80% Acetone (4:1 Acetone Ethyl Alcohol) in a pestle mortar with a pinchful of fine sand. The supernatant part from this ground material was centrifuged at 3000 rpm in a centrifuge for 5 minutes. Residue was washed repeatedly and centrifuged until it lacked green colour in the remaining plant material (Bray, 1960). The supernatant chlorophyll solution was diluted to 50 ml with 80% acetone and analysed in colorimeter at wave-length of 6450 A° and 6650 A°, chlorophyll concentrations were ascertained using Coefficient of Arnon (1949) and Bray (1960).

$$\text{Chl. a. } (\text{mg/g}^{-1}) = \frac{12.7 \times 665 - 2.69 \times 645 \times 50}{1000 \times \text{wt}}$$

$$\text{Chl. b. } (\text{mg/g}^{-1}) = \frac{22.9 \times 645 - 4.68 \times 665 \times 50}{1000 \times \text{wt}}$$

On the other hand the extract was also tested at 4800 A° and 5100 A° wave-length for estimating carotenoids.

$$\text{Carotenoids } (mg/g^{-1}) = \frac{7.6 \times 480 - 1.49 \times 510 \times 50}{1000 \times wt}$$

At the same time a fresh sample of the same weight was taken to find out its dry weight by drying in an oven at 80°C for 24 hours.

The results were computed in mg chlorophyll per gm of dry weight and mg chlorophyll per m^2 of ground area.

Observation

Variation in the leaf Area and Photosynthetic phytomass

From Table IV 7 it is evident that the community attained its maximum L.A.I. 6.26 m^2/m^2 and photosynthetic phytomass (live green) 351.04 g/m^2 in the month of August (last week) after which value decreased continuously and gradually upto May, when a minimum value of 0.44 m^2/m^2 and 31.42 g/m^2 was obtained respectively, except a slight increase in March 1.57 m^2/m^2 and 88.40 g/m^2 due to unusual late winter rains.

The L.A.I. value decreased from its maximum value of 6.26 m^2/m^2 in August (last week) through September 5.75 m^2/m^2, October 5.25 m^2/m^2, November 4.84 m^2/m^2, July 2.53 m^2/m^2 and 2.52 m^2/m^2 in December, reaching to a minimum value of 0.44 m^2/m^2 in May. Thus the higher L.A.I. values were obtained throughout the growth period. Its value started increasing with the onset of monsoon.

Table IV 7: Leaf Area/L.A.I. and Photosynthetic phytomass

Months	Phytomass (green) g/m^2	Leaf area cm^2/m^2	L.A.I. m^2/m^2
July	141.32	25335	2.53
August	351.04	62685	6.26
September	322.56	57598	5.75
October	301.37	52598	5.25
November	271.39	48456	4.84
December	150.99	25254	2.52
January	100.18	18138	1.81
February	83.40	14890	1.48
March	88.40	15784	1.57
April	70.04	10375	1.03
May	31. 42	4476	0.44
June	64.07	11440	1.14

Total Chlorophyll and Carotenoid content per unit dry weight of leaf

As evident in the Table IV 8 chlorophyll concentration (mg/g^{-1} dry wt) revealed a sharp variation during the whole year. Soon with the advent of rain total chlorophyll concentration of the community increased rapidly reaching the peak(3.84 mg/g^{-1}) in July (last week). Total chlorophyll remained high throughout the rainy months (Fig. 9). After attaining peak concentration the value gradually declined till December. Again in the month of January the concentration increased slightly, showing a second peak due to winter showers (2.52 mg/g^{-1}). The minimum concentration(0.85 mg/g^{-1}) was obtained in the month of May. It was further observed that chlorophyll concentration again increased, though very little (2.45 mg/g^{-1}) in the month of March due to unusual rains. Like chlorophyll, carotenoids also showed a considerable variation throughout the year with a maximum value of 1.02 mg/g^{-1} in July and a minimum of 0.32 mg/g^{-1} in May, except a small rise in March (0.46 mg/g^{-1}). Thus in comparison to chlorophyll carotenoids showed a gradual and steady fall in concentration.

Chlorophyll and Carotenoids contents on unit area basis

Chlorophyll and carotenoid contents on per metre square ground area basis was calculated by multiplying the pigment concentration (mg/g^{-1}) with the dry weight of the aboveground live green phytomass per metre square area.

Table IV 8: Chlorophyll and Carotenoid contents

Months	Per Unit Dry wt. of Leaf (mg/g^{-1})		Per Unit ground area (g/m^2)		Phytomass (Green) g/m^2
	Chlorophyll	Carotenoid	Chlorophyll	Carotenoid	
July	3.81	1.02	0.54	0.14	141.32
August	3.59	0.75	1.26	0.26	351.04
September	3.53	0.72	1.14	0.23	322.56
October	3.19	0.62	0.96	0.19	301.37
November	2.10	0.58	0.57	0.16	271.39
December	1.88	0.56	0.28	0.08	150.99
January	2.52	0.51	0.25	0.05	100.18
February	2.41	0.42	0.20	0.03	83.40
March	2.45	0.46	0.22	0.04	88.40
April	1.18	0.36	0.08	0.03	70.04
May	0.85	0.32	0.03	0.01	31.42
June	1.08	0.38	0.07	0.02	64.07

On perusal of the Table IV 8, the total chlorophyll content showed a sharp increase with the advent of rains, it reached to its peak value of 1.26 g/m^2 in August (Fig. 9) and then gradually declined till May with a minimum value of 0.03 g/m^2, except a small rise in value 0.22 g/m^2 in March.

The carotenoids also showed the same trend with a maximum content of 0.26 g/m^2 in August and a minimum of 0.01 g/m^2 in May. These fluctuations may be due to variations in standing crop of aboveground green phytomass for which precipitation plays a critical role.

Chlorophyll and carotenoids values (g/m^2) were remarkably high in the growth period due to higher dry weight of photosynthetic part of the vegetation.

DISCUSSION

Leaf area

During rainy season, the impact of high moisture, intermittent light and warm temperature was reflected in greater leaf area, - Leaf area index (L.A.I.) and photosynthetic green phytomass as evident by Table IV 7. The maximum L.A.I. was found(6.25 m^2/m^2)in August. The winter season exhibited an intermediate position but increasing temperature and light intensity of summer months have lowered the L.A.I. which was found minimum in May (0.44 m^2/m^2), may be because the moisture in soil and air decreased and acted as a limiting factor in the growth of the photosynthetic phytomass. The

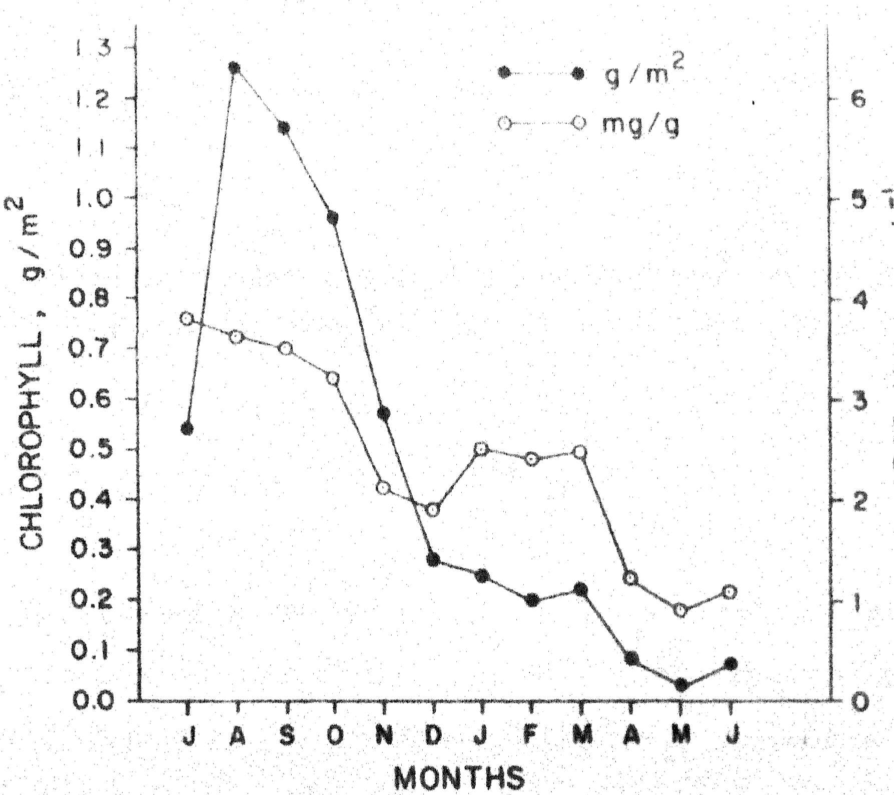


FIG. 9 – MONTHLY VARIATION IN TOTAL CHLOROPHYLL

reduction in photosynthetic phytomass and corresponding decline in L.A.I. during winter and summer may further be attributed to completion of the life cycle in annuals and wilting and shedding of leaves in perennials.

The maximum L.A.I. and photosynthetic phytomass during rainy season may be attributed to the increased availability of soil moisture and nutrients and corresponding increase in the number of leaves. The slight increase in L.A.I. and phytomass during March might have been due to the winter and spring showers resulting into the sprouting of fresh tillers.

Monsi and Saeki (1953) reported, the L.A.I. of natural community may vary from 4 to 7 m^2/m^2 for herbaceous community. The present findings are in conformity with the above report and also to that of Billore (1973).

The variables viz. L.A.I. and photosynthetic green phytomass were treated statistically to evaluate the degree of relation between them (Fig. 10) which resulted in a highly significant positive correlation between these two parameters ($r = 0.99$, $P < .001$). It envisages that the green phytomass increases with an increase in the L.A.I.. Therefore, it may be pointed out here that the leaf area index is the key factor for organic matter accumulation.

<u>Chlorophyll</u>

The potentiality of the leaves to photosynthesize vary with pigment concentration together with CO_2, light and temperature.

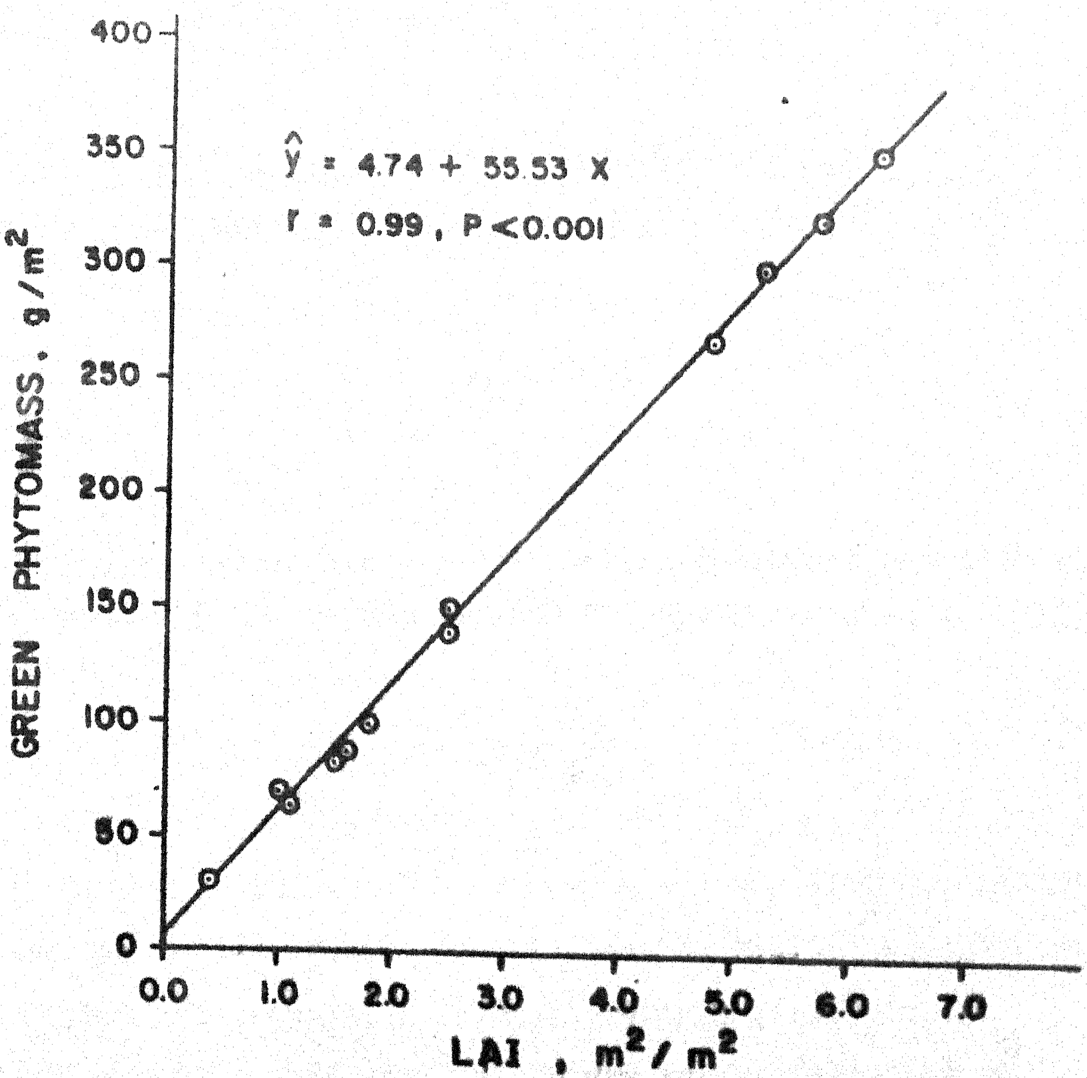


FIG. 10 - RELATIONSHIP BETWEEN LAI AND GREEN PHYTOMASS.

The chlorophyll concentration mg/g^{-1} on dry weight basis revealed a distinct variation throughout the year as evident by Table IV 8. The maximum total chlorophyll concentration was obtained in July (rainy season) followed by a declining trend till May, except for a small rise in January. This maximum chlorophyll concentration in July is due to most favourable climatic conditions for high rate of primary production viz. warm temperature, intermittent light, high soil moisture etc. The chlorophyll concentration remained approximately constant during the rainy season due to homogeneous preponderance of chlorophyll in the entire vegetation. The decrease in concentration till May is attributed to the limiting soil moisture as well as to the detrimental effects of intense light and high temperature to chlsrophyll (Meyer _et al_. 1960).

The chlorophyll _b_ concentration was found significantly higher than chlorophyll _a_ throughout the study period. This lower concentration of chlorophyll _a_ may be due to the possible conversion of chlorophyll _a_ into chlorophyll _b_ (Rebeiz and Castelfraco, 1973). It may also be due to the fact that small fraction of chlorophyll _a_ gets converted to phaeophytin _a_ which is stable enough to remain for long periods (Gorham, 1959; Gorham and Sanger, 1967).

Under the present investigations higher proportion of chlorophyll _b_, signifies its active role in photosynthesis than chlorophyll _a_ pigment. These findings are quite similar to those of Nandpuri et al. (1973 ,Ludhiana), Radha Rani (1976, Varanasi) and Misra (1980, Varanasi).

On ground area basis, total chlorophyll content (g/m^2) of the community reached peak value in August and thereafter decreased continuously upto May. This trend of variation may be due to the availability of sufficient moisture, optimum light and temperature conditions during rainy season; and extreme fluctuations in light and temperature and low moisture during winter and summer months which have not favoured the chlorophyll content of community. The maximum chlorophyll content ($1.26 g/m^2$) of the present investigation is slightly higher than the values of many temperate communities (0.3 to 1.0 g/m^2)(Bray ,1960) and to that of Billore (1976).

The variation in chlorophyll concentration affected significantly the organic matter accumulation and photosynthetic phytomass increases and decreases almost simultaneously.

Statistically a high significant positive correlation coefficient ($r = 0.97$, $P < 0.001$) was computed for the relationship in between the chlorophyll concentration and photosynthetic green phytomass (Fig. 11). It shows that with the increase in chlorophyll concentration the phytomass increases (Kumar, 1971; Billore and Mall, 1976; and Joshi, 1978), which in turn may result in an enhancement of the net production, as has previously been shown by Gill (1975) that chlorophyll concentration was positively related with the net production. Bliss(1966) and Tiessen and Bonde(1967) reported a very high correlation between chlorophyll and dry weight in Arctic and Alpine ecosystems.

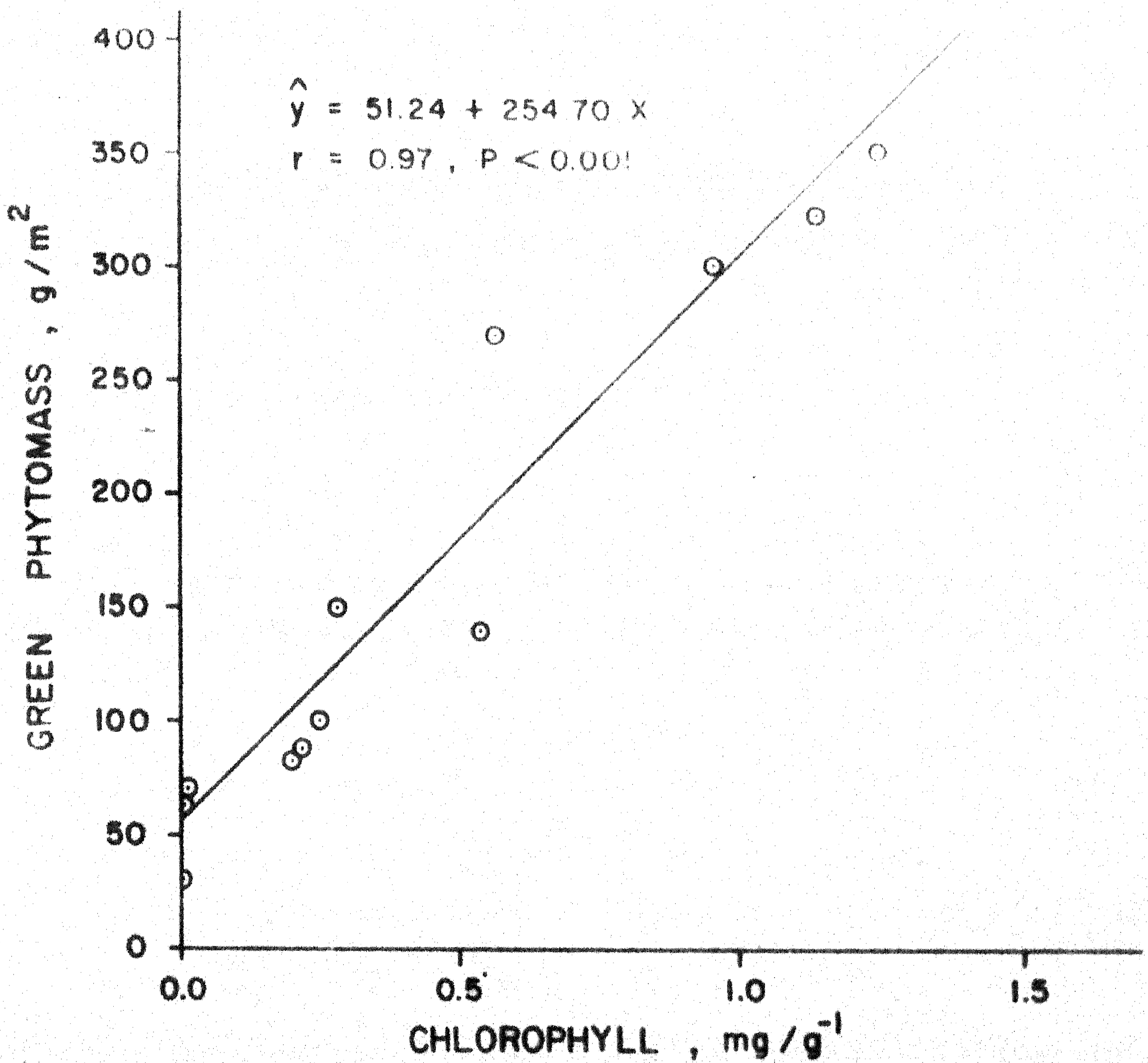


FIG. 11 – RELATIONSHIP BETWEEN CHLOROPHYLL CONCENTRATION AND GREEN PHYTOMASS.

CHAPTER V

ORGANIC PRODUCTION

SECTION A

PRODUCTION DYNAMICS

Productivity being an attribute of community function (Odum, 1960-62) has attracted much attention in recent years. The organic matter in-put to an ecosystem by the autotrophs during a given period of time is a measure of rate of primary production. 'Gross primary productivity' is the total conversion through photosynthesis plus mineral uptake but net primary production (N.P.P.) is the rate of storage of organic matter in plants after autotrophic respiration, however, it includes all losses due to litter fall, biotic interferences etc. N.P.P. is usually measured as net dry organic matter synthesized per unit area per unit time and is usually expressed as $g/m^2/year$.

Net primary production studies conducted in the grasslands at Varanasi have given basic information on organic productivity in India (Singh, 1967; Chowdhary, 1967; Agarwal, 1970; Maurya, 1970; Tripathi, 1970; Singh, 1972a and Singh, 1972b). Pandeya and Jayan(1970)studied N.P.P. of Ahmedabad grassland. Singh and Yadav (1971) obtained N.P.P. in grassland ecosystem at Kurukshetra. Net primary productivity studies have also been conducted by different authors at various places:

Mall and Singh	1971 at Ujjain
Misra	1973 at Ujjain
Billore	1973 at Ratlam
Naik	1973 at Ambikapur
Asthana	1974 at Gorakhpur
Das	1975 at Allahabad
Gupta	1976 at Jhansi
Trivedi	1976 at Jhansi
Pandey	1977 at Varanasi
Singh	1978 at Varanasi
Agnihotri	1979 at Mandla

METHODS

In all these studies data of phytomass at monthly intervals form the basis of computation of net production. The above ground net primary productivity is usually represented by the peak standing crop i.e. the total dry weight of herbage at the end of the growing season (Hadley and Kieckhefer, 1963) or by the sum total of maximum weight attained by the individual species (Odum, 1960; Golley, 1965; Sims and Singh, 1971).

Naik and Mishra (1974) calculated the above ground primary productivity by employing the following methods:

(a) Summation of peak phytomass values of all the component species alongwith the peak value of litter.

(b) By modified Weigert Evans method (Lomnicki et al., 1968). Summation of peak method may yield an estimate nearly two times that of peak community standing crop (Malone, 1968). Weigert and Evans (1964) reported that peak standing crop will be identical to net primary production only where all the individuals present in a community attain maturity at the same time and where mortality occurs only during the post growth period. In complex vegetation, the peak standing crop may be only 50% of the real net production.

Mall and Billore (1974) calculated the net community productivity by summation of species wise positive increases in aboveground live phytomass, to which is added the sum totals of positive increases in standing dead (upto growth period only) and sum totals of positive increases in underground phytomass throughout the year as proposed by Singh et al. (1974).

According to Singh et al. (1974) 'No single standard technique of computation is available which could give comparable estimate account of grasslands types'.

In the present investigation aboveground net production (A.N.P.) has been accounted by summing the total positive changes in the aboveground live phytomass on successive sampling dates throughout the year, plus positive changes in standing dead and litter phytomass for only those sampling intervals during which a positive difference also occurred

in aboveground live phytomass (1st method). The last two phytomass changes are regarded as the production and not reflected in live phytomass increment. Compartmentwise productivity was also calculated separately (2nd method). The original difference method (Ovington et al.,1963) was also used to get a comparative picture of net production i.e. summation of positive increases in the total aboveground standing crop (standing live,standing dead and litter) throughout the year (3rd method).

The underground net production (U.N.P.) has been estimated by summing the positive increases in phytomass on successive sampling dates throughout the year.

Total net productivity (T.N.P.) was obtained by adding aboveground net production and underground net production for the three different seasons and on an annual basis.

The rate of production was evaluated by dividing the net production for the different seasons and for the year by number of days.

Production studies

As described earlier the difference of phytomass values between two consecutive months gives net production in that period. Therefore, the productivity of different components of the two compartments of the community have been calculated separately by deducting the phytomass values of the preceding month from the current month,as well as on community basis.

Standing live production

As evident in the Table V 1a on protected stand the maximum production was recorded in the month of August

Table V 1b: Monthly production of different components (g/m^2)

(Protected stand)

Months	St. Live	St. Dead	Underground
June	-	-	-
July	211.28	-92.05	53.94
August	487.33	-29.41	102.45
September	179.36	124.78	120.47
October	276.93	149.64	119.37
November	-289.13	196.59	144.69
December	-524.89	76.40	-104.88
January	139.15	-78.23	65.21
February	-96.11	50.87	-170.40
March	-135.50	-224.16	-121.05
April	-127.35	-160.68	-133.65
May	-116.27	9.00	-14.85
June	55.64	-44.88	24.85

Table V 1b: Monthly production of different components (g/m^2)

(Grazed stand)

Months	St. Live	St. Dead	Underground
June	-	-	-
July	86.50	-9.89	22.98
August	163.23	10.68	77.83
September	71.58	26.55	99.81
October	-87.96	19.38	85.02
November	-129.09	46.00	-65.12
December	-104.87	-37.09	-46.44
January	33.96	-27.45	32.49
February	-16.35	-14.34	2.63
March	-26.10	2.89	-51.75
April	-8.93	-10.44	-72.82
May	-11.23	-8.03	-26.89
June	35.94	-1.46	-33.29

(487.33 g/m^2) followed by October, July, September, January and June with a minimum production (55.64 g/m^2). Negative values have been observed in the month of November, December, February, March, April and May. While on grazed stand (Table V 1b), maximum production was also recorded in the month of August (163.23 g/m^2) followed by July, September, June and January with a minimum value (33.96 g/m^2). In the rest of months of the study period a negative production was observed. Considering the production values of the two compartments of the protected community separately (Table V 2a), the maximum production does not coincide in the same month. For grasses (compartment A) the maximum production was in August (472.41 g/m^2) and for non-grasses (compartment B) in October (41.87 g/m^2). Thus it was observed that compartment A (the dominant grass Dichanthium annulatum) contributed a major portion in the standing live production in the month of August, Similarly, on the grazed stand (Table V 2b) the maximum production in the two compartments separately also does not coincide in the same month. Grasses recorded maximum production in July (53.49 g/m^2) and non-grasses in August (129.41 g/m^2). As compared to protected stand, non-grasses contribute a major share in the month of August on grazed stand.

Standing dead production

Standing dead production on the monthly basis revealed that on protected stand maximum production was in November

Table V 2a: Monthly production of different components in the two compartments (g/m^2) (Protected stand)

Months	Grasses (Compartment A)			Non-grasses (Compartment B)		
	St. Live	St. Dead	Under-ground	St. Live	St. Dead	Under-ground
June	-	-	-	-	-	-
July	202.50	-89.90	50.32	8.78	-	3.62
August	472.41	-29.41	93.53	14.92	-	8.92
September	158.32	119.41	113.35	21.04	5.37	7.12
October	235.06	134.85	111.60	41.87	14.79	7.77
November	-249.86	186.59	135.58	-39.27	10.00	9.11
December	-485.21	82.08	-82.26	-39.68	-5.68	-22.62
January	133.01	-65.68	59.64	6.14	-12.55	5.57
February	-85.95	59.36	-159.16	-10.16	- 8.49	-11.24
March	-132.24	-222.72	-115.84	-3.26	-1.44	-5.21
April	-124.24	-159.54	-132.15	-2.91	-1.14	-1.50
May	-115.90	09.34	-13.61	-0.37	-0.34	-1.24
June	51.37	-45.46	24.45	4.27	-0.58	0.40

Table V 2b: Monthly production of different components in the two compartments (g/m^2) (Grazed stand)

Months	Grasses (Compartment A)			Non-grasses (Compartment B)		
	St. Live	St. Dead	Under-ground	St. Live	St. Dead	Under-ground
June	-	-	-	-	-	-
July	53.49	-	13.14	33.01	-	9.84
August	33.82	8.60	61.04	129.41	2.08	16.79
September	-45.31	18.55	68.64	116.89	8.00	31.17
October	-34.84	-2.99	48.77	-53.12	22.37	36.25
November	26.96	-6.11	-36.84	-156.05	52.11	-38.28
December	-40.23	17.39	-25.74	-64.64	-54.48	-20.70
January	28.35	-12.24	30.93	5.61	-15.21	1.56
February	-9.19	-1.77	18.72	-7.16	-12.57	-16.09
March	-22.73	4.64	-39.85	-3.37	0.25	-13.90
April	-5.61	-10.91	-66.36	- 3.32	-1.53	-4.46
May	-9.52	-7.01	-22.85	-1.71	-	-2.73
June	29.32	-1.46	-29.44	6.62	-	6.62

(196.59 g/m^2) followed by October, September, December, February and May. Negative values have been observed in the remaining period of the year. Similarly, on the grazed stand maximum standing dead production was also observed in November (46.00 g/m^2), followed by September, October, August and March. Standing dead production values of the two compartments (A and B) revealed their maximum values in November (186.59 g/m^2) and October (14.79 g/m^2) respectively on protected stand, while grazed stand revealed maximum value (18.55 g/m^2) in September for grasses and (52.11 g/m^2) in November for non-grasses.

Underground production

The monthly data of underground production revealed a considerable variation throughout the study period on protected stand, as evident in the Table V 1a. The maximum underground production was recorded (144.69 g/m^2) in November and minimum (24.85 g/m^2) in June. The other months of underground production were September, October, August, January and July. The remaining period of the year showed negative values. Similarly on grazed stand (Table V 1b), maximum underground production was recorded (99.81 g/m^2) in September and minimum (2.63 g/m^2) in February. The other months of underground production were October, August, January and July.

The underground production values of the two compartments (A and B) in the case of protected stand, also follow the same

trend with their maximum values (135.58 g/m^2 and 9.11 g/m^2) in November as evident in the Table V 2a, while on grazed stand the underground production values of the two compartments revealed maximum values in different months, Compartment A in September with a value of 68.64 g/m^2 and Compartment B in October with a value of 36.25 g/m^2 (Table V 2b).

Aboveground net production (A.N.P.)

It has been calculated from the positive increases in the standing live phytomass plus concomittent increases in the standing dead and litter phytomass. Positive increases in standing live and standing dead have been given in Table V 1 and 2 . Litter production has been given in Section B of this chapter (Table V 6).

On perusal of these tables, the maximum aboveground net production was recorded (508.35 g/m^2) in October and minimum (55.64 g/m^2) in June. January with a production value of 139.15 g/m^2 occupied an intermediate position on protected stand.

Parallel to this on grazed stand, maximum A.N.P. (173.91 g/m^2) was recorded in August, minimum (33.96 g/m^2) in January and June revealed a value (35.94 g/m^2) slightly higher to the minimum value.

Seasonal net productivity and rate

On seasonal basis aboveground net production has been estimated by calculating/summing positive value of the

respective components between the successive months pertaining to the respective season.

It is evident from Table V 3 for protected stand, that rainy season has got the maximum A.N.P. 1568.29 g/m^2 with a rate of 12.75 $g/m^2/day$. Winter season occupied an intermediate position with a value of 139.15 g/m^2 and rate 1.16 $g/m^2/day$. The minimum A.N.P. value of 55.64 g/m^2 was recorded in summer season with a rate of 0.45 $g/m^2/day$.

Similarly, on the grazed stand the rainy season recorded maximum A.N.P. 378.86 g/m^2 with a rate of 3.08 $g/m^2/day$. But the minimum A.N.P. was recorded in winter 33.96 g/m^2 with a rate of 0.28 $g/m^2/day$ (Table V 3), as compared to summer season on protected stand.

Out of the total annual aboveground net production value i.e. 1763.08 g/m^2 (4.83 $g/m^2/day$) on protected stand, rainy season contribution was 88.9%, winter season and summer season 7.9% and 3.2% respectively. The average daily production for the whole year was 4.83 $g/m^2/day$.

Similarly on the grazed stand, out of the total annual aboveground net production value i.e. 448.76 g/m^2 (1.23 $g/m^2/day$), rainy season share was 84.4%, winter season and summer season 7.5% and 8.1% respectively. The average daily production for the whole year was 1.23 $g/m^2/day$.

Compartment wise estimation of aboveground net production for the protected stand revealed the same values

Table V 3: Seasonal and annual Net production* (g/m^2) and its rate ($g/m^2/day$)

Protected stand

	Rainy season		Winter season		Summer season		Annual	
Aboveground	1568.29	(12.75)	139.15	(1.16)	55.64	(0.45)	1763.08	(4.83)
Underground	396.23	(3.21)	209.90	(1.74)	24.85	(0.20)	630.98	(1.73)
Total	1964.52	(15.96)	349.05	(2.90)	80.49	(0.65)	2394.06	(6.56)

Grazed stand

	Rainy season		Winter season		Summer season		Annual	
Aboveground	378.86	(3.08)	33.96	(0.28)	35.94	(0.29)	448.76	(1.23)
Underground	285.64	(2.32)	35.12	(0.29)	-	-	320.76	(0.88)
Total	664.50	(5.40)	69.08	(0.57)	35.94	(0.29)	769.52	(2.10)

* Litter production addition has been made

Values in parantheses are of the rate of net production.

(Table V 4) i.e. total annual aboveground net production 1763.08 g/m^2 with a rate of 4.83 $g/m^2/day$. Out of the total annual A.N.P., grasses (Compartment A) contributed 1506.93 g/m^2 (85.4%), nongrasses (Compartment B) contribution was 117.18 g/m^2 (6.6%) and litter share was 138.97 g/m^2 (7.8%). Seasonal estimation showed maximum A.N.P. by the two compartments in the rainy season with a value of 1322.55 g/m^2 (10.75 $g/m^2/day$) and 106.77 g/m^2 (0.86 $g/m^2/day$) respectively. The minimum A.N.P. was obtained in summer season with a value of 51.37 g/m^2 (0.42 $g/m^2/day$) and 4.27 g/m^2 (0.03 $g/m^2/day$) for compartments A and B respectively.

On grazed stand, compartment wise estimation of total A.N.P. by the same method revealed slightly higher values to that of total community (Table V 4). Total annual aboveground net production was recorded as 502.48 g/m^2 (rate 1.37 $g/m^2/day$) out of which compartment A contributed 180.54 g/m^2 (35.9%), compartment B 302.62 g/m^2 (60.2%) and litter share was 20.32 g/m^2 (4.0%). Thus compartment B share was more than compartment A, if compared to protected stand. Seasonal estimation recorded maximum production by the two compartments in the rainy season (though maximum production in separate months) with a value of 95.91 g/m^2 (0.78 $g/m^2/day$) and 289.39 g/m^2 (2.35 $g/m^2/day$) respectively. The minimum value was recorded in summer season 29.32 g/m^2 (0.24 $g/m^2/day$) and 6.62 g/m^2 (0.05 $g/m^2/day$) for compartments A and B respectively.

Table V 4: Seasonal and annual Net production (g/m^2) and its rate (g/m^2/day)

Protected stand

	Rainy season		Winter season		Summer season		Annual	
Aboveground								
Compartment A	1322.55	(10.75)	133.01	(1.10)	51.37	(0.42)	1506.93	(4.12)
Compartment B	106.77	(0.86)	6.14	(0.05)	4.27	(0.03)	117.18	(0.32)
Litter	138.97	(1.12)	-	-	-	-	138.97	(0.38)
Total aboveground	1568.29	(12.75)	139.15	(1.15)	55.64	(0.45)	1763.08	(4.83)
Underground								
Compartment A	368.80	(2.99)	195.22	(1.62)	24.45	(0.20)	588.47	(1.61)
Compartment B	27.43	(0.22)	14.68	(0.12)	0.40	(0.003)	42.51	(0.11)
Total underground	396.23	(3.22)	209.90	(1.74)	24.85	(0.20)	630.98	(1.73)
Total net production	1964.52	(15.97)	349.05	(2.92)	80.49	(0.65)	2394.06	(6.56)

Grazed stand

	Rainy season		Winter season		Summer season		Annual	
Aboveground								
Compartment A	95.91	(0.78)	55.31	(0.46)	29.32	(0.24)	180.54	(0.49)
Compartment B	289.39	(2.35)	5.61	(0.04)	6.62	(0.05)	302.62	(0.83)
Litter	20.32	(0.16)	-	-	-	-	20.32	(0.16)
Total aboveground	405.62	(3.29)	60.92	(0.50)	35.94	(0.29)	502.48	(1.37)
Underground								
Compartment A	191.59	(1.56)	49.65	(0.41)	-	-	241.24	(0.66)
Compartment B	94.05	(0.76)	1.56	(0.01)	-	-	95.61	(0.23)
Total underground	285.64	(2.32)	51.21	(0.43)	-	-	336.85	(0.92)
Total net production	691.26	(5.62)	112.13	(0.93)	35.94	(0.29)	839.33	(2.29)

While the annual A.N.P. computed by 3rd method with a value of 1309.53 g/m^2 (3.6 $g/m^2/day$) was found lower to the values obtained by 1st and 2nd methods on protected stand. Similarly on grazed stand, the annual A.N.P. value of 394.17 g/m^2 (1.08 $g/m^2/day$) was also found lower than the values obtained by 1st and 2nd methods. It was observed that only rainy season accounted for annual aboveground net production on both the stands, when computed by the difference method.

Underground Net production (U.N.P.)

As evident in the Table V 1a maximum underground net production was recorded (144.69 g/m^2) in November and minimum (24.85 g/m^2) in June on protected stand. While in the case of grazed stand, the maximum underground net production(99.81 g/m^2) was recorded in September and minimum (2.63 g/m^2) in February (Table V 1b).

Seasonal contribution

A perusal of the Table V 3 for protected stand, clearly indicate that the U.N.P. was maximum 396.23 g/m^2 in rainy season with a rate of 3.21 $g/m^2/day$ and minimum 24.85 g/m^2 during summer season with a rate of 0.20 $g/m^2/day$. Winter season with a value of 209.90 g/m^2 and rate 1.74 $g/m^2/day$ occupied an intermediate position. The annual underground net production accounted was 630.98 g/m^2 with a production rate of 1.73 $g/m^2/day$.

Similarly, on the grazed stand, the maximum U.N.P. was recorded in rainy season(285.64 g/m^2)with a rate of 2.32 $g/m^2/day$. Winter season recorded lowest value≈35.12 g/m^2 and rate 0.29 $g/m^2/day$, while no production was observed in summer season. The annual underground net production was 320.76 g/m^2 with a production rate of 0.88 $g/m^2/day$ (Table V 3).

Seasonal estimation of compartment wise U.N.P. on protected stand revealed the same values i.e. maximum production in rainy season(396.23 g/m^2)with a rate of 3.22 $g/m^2/day$. The major share was of Compartment A (92.0%) than Compartment B (8%). The minimum value of 24.85 g/m^2 was in summer and winter season with a value of 209.90 g/m^2 occupied an intermediate position. The annual underground net production estimated was 630.98 g/m^2 with a rate of 1.73 $g/m^2/day$ (Table V 4).

Compartment wise estimation of U.N.P. on grazed stand revealed the same value in rainy season but the values of winter season slightly differed from the first computation. In winter season compartment A recorded 49.65 g/m^2 (0.41 $g/m^2/day$) and compartment B 1.56 g/m^2 (0.01 $g/m^2/day$) with a total production of 51.21 g/m^2 and rate 0.43 $g/m^2/day$. The annual underground net production was recorded as 336.85 g/m^2 with a rate of 0.92 $g/m^2/day$ (Table V 4).

<u>Total Net Production</u> (T.N.P.)

Total net production values as accounted by three different methods:-

Protected stand	T.N.P.	Rate
1st method	2394.06 g/m^2	6.56 $g/m^2/day$
2nd method	2394.06 "	6.56 "
3rd method	1940.51 "	5.32 "

The value obtained by 1st method is slightly higher than the value obtained by difference method (3rd).

Similarly on grazed stand T.N.P. computed by these methods are:-

	T.N.P.	Rate
1st method	769.52 g/m^2	2.10 $g/m^2/day$
2nd method	839.33 "	2.29 "
3rd method	714.93 "	1.96 "

The value obtained by difference method (3rd) is perhaps an under estimation because the values of live, standing dead, and litter have been compounded for each sampling date.

Compartment wise estimation of total net production (2nd method) recorded the same value as that of first method in protected stand but slightly different value was obtained in the same of grazed stand, this is obviously due to the fact that compartment wise production have been compounded in 1st method.

The values obtained by 1st method will form the basis for further computation for both the stands.

Thus out of the total net production of the community, A.N.P. contributed 1763.08 g/m^2 (73.6%) and U.N.P. 630.98 g/m^2 (26.3%) on an annual basis on protected stand.

Similarly on grazed stand, A.N.P. contribution was 448.76 g/m^2 (58.31%) and U.N.P. 320.76 g/m^2 (41.69%).

DISCUSSION

In grasslands the annual primary productivity is largely influenced by the amount and distribution of rainfall. Higher rainfall in tropics increases the productivity(Whyte ;1975). The rainy season found to be more favourable for accumulation of assimilates in the aboveground parts, when the green portion of the annuals and perennials show maximum growth. Further, in rainy season there is an increase in the standing crop due to an increase in number of species. Therefore, the highest productivity is found in rainy season.

In the present investigation higher A.N.P. was obtained in rainy season when light was interrupted by the clouds and other factors like moisture was also abundant. According to Helms (1965) foggy atmosphere increases the rate of production. Fog probably creates favourable moisture condition in foliage with a more efficient distribution of light, resulting into more chlorophyll content and more production.

Total A.N.P. of community was more (1763.08 g/m^2) on protected stand than on grazed stand (448.76 g/m^2), which experiences more intense herbage removal due to heavy grazing by large herbivores. The factor of protection seems to be responsible for increased production on protected stand and biotic interferences decrease the net production on grazed stand.

On protected stand, out of total A.N.P. (1568.29 g/m^2) during rainy season, 73% was reflected in the standing live, 18% in the standing dead and only 9% was reflected in the litter component. Similarly on grazed stand, out of total A.N.P. (378.86 g/m^2), standing live, standing dead and litter shared 84.8, 9.82 and 5.4 % respectively. It was observed that most of the total production was contributed by dominant grasses (85.4%) on protected stand but by nongrasses (55%) on grazed stand.

In summer season A.N.P. accounted only for 3.1% and 8.0% of the total A.N.P. on protected and grazed stands respectively. It may be due to the presence of extremely hot and dry conditions resulting into more losses than growth.

Winter season occupied an intermediate position on both the stands, thus A.N.P. of the community clearly showed that the amount as well as the rate of productivity differ from season to season (Table V 3).

The maximum underground net production (U.N.P.) was observed during rainy season (postmonsoon period) at both

the stands, followed by winter and summer seasons. The high U.N.P. of rainy season may be due to extensive development of root system and downward translocation of photosynthate from aboveground plant parts to supplement the growth of root system. It was recorded that grasses contributed 93 and 67% to the total U.N.P. of both the stands respectively.

Winter season occupied an intermediate position and minimum or no production was observed in summer. The scorching sun and low moisture content during summer season have caused the withering and death of aboveground components which may result into the subsequent death and losses of underground components.

Total U.N.P. for the two stands were observed as 630.98 g/m^2 and 320.76 g/m^2. The lower U.N.P. on grazed stand may be attributed mainly to the constant removal of herbage aboveground. Trivedi(1976) reported one and a half time more U.N.P. at protected stand than grazed stand.

In the present investigation, total net community production (T.N.P.) was 2394.06 g/m^2 with a production rate 6.56 g/m^2/day for protected stand and 769.52 g/m^2 with a rate of 2.10 g/m^2/day for grazed stand. Out of the T.N.P. of two communities, A.N.P. and U.N.P. share was 74 and 26% on protected stand and 58 and 42% on grazed stand.

Standing phytomass and production values of aboveground components, were relatively higher than that of underground components. Jain (1971) observed about 66% of the T.N.P. contributed by the aerial parts in protected stand.

The significantly less contribution of U.N.P. to T.N.P. as compared to A.N.P. may be due to the concentration of autotrophic activities in aboveground components and continuous losses in underground components because of sloughing of root hairs, root caps, microbial activity and consumption by soil animals (Dahlman and Kucera, 1965; Singh 1967; Lieth, 1968; Sims and Singh, 1971). Temperature being not too low in soils, the decomposition of underground components proceeds at a fast rate because of the abundance of substrates for microbes (Singh and Yadav, 1974).

T.N.P. as well as A.N.P. and U.N.P. have been compared with various tropical grasslands values (Table V 5). It is clear from the table that yearly production of this protected grassland is much higher than other grasslands e.g. Choudhary (1972, Varanasi), Varshney (1972, Delhi), Misra (1973, Ujjain), Naik (1973, Ambikapur), Billore (1973, Ratlam), Dakwale (1975, Sagar), Gupta (1976, Jhansi), Billore (1978, Ujjain) and Agnihotri (1979, Mandla), but the value is quite similar to that of Sagar grassland dominated by Dichanthium annulatum (Jain, 1971) and lower to other grasslands e.g. Singh (1972a, Varanasi), Singh and Yadav (1974, Kurukshetra), Trivedi (1976, Jhansi). On the other hand the value of grazed stand

is lower to other reports because of herbage removal due to heavy grazing. However, the T.N.P. value of both the stands fall within the range of T.N.P. of tropical grasslands.

Plant community under grazing showed 26.6% loss in Eastern Idaho (Pearson, 1965b), 34.9% in Sagar (Jain, 1971), 57.9% in a Varanasi grassland (Singh, 1972b), 51.0% in Ambikapur grassland (Naik, 1973) and 36.5% in Mandla grassland (Agnihotri, 1979). In the present investigation 67.8% loss is recorded. This high value may be explained due to heavy grazing pressure.

A comparative account of productivity of some tropical grasslands at the rate of ton/ha/yr^{-1} is given below:-

Community	Place	Productivity (ton/ha/yr^{-1})	Authors
Dichanthium grassland	Sagar	23	Jain 1971
Dichanthium grassland	Varanasi	13.5	Ambashta *et al.* 1972
Heteropogon grassland	Varanasi	28.8	Ambashta *et al.* 1972
Heteropogon grassland	Delhi	13.4	Varshney 1972
Dichanthium grassland	Varanasi	10.5	Choudhary 1972
Mixed grassland	Kurukshetra	23.3	Singh & Yadav 1972
Sehima grassland	Ratlam	8.4	Billore 1973
Dichanthium grassland	Ujjain	9.8	Misra 1973
Dichanthium grassland	Dhakarwara	16	Trivedi 1976
Dichanthium grassland	Ujjain	11	Billore 1978
Apluda grassland	Udaipur	5.1	Vyas & Vyas 1978
Dichanthium grassland	Orai	23	Present study 1980
Dichanthium grassland	Orai	7	" 1980

A perusal of the above indicates that the productivity of the present grassland is more or less equal to that of Sagar grassland (Jain, 1971), Varanasi grassland (Ambashta *et al.*, 1972) but higher to other grasslands dominated by *Dichanthium annulatum*. It is about 4.5 times more than the average temperate rate of 5 ton/ha/yr^{-1} (Whittaker, 1970). Thus, the present grasslands are highly productive with annual rate of production 6.5 g/m^2/day and 2.1 g/m^2/day as compared to other tropical and even some temperate grasslands. It may be ascribed due to the rainfall and corresponding vigorous and robust growth of the dominant species *D. annulatum*.

It has been shown that tropical and subtropical grasslands are more productive than temperate grasslands. As quoted, 'This difference may be due to the differences in the mechanism of carbon fixation in the tropical and temperate plants. Many tropical grasses and forbs fix carbon by the C_4 pathway while temperate grasses usually follow C_3 pathway. The C_4 pathway permits photosynthesis at high light intensities with lower losses to respiration (Goldsworthy, 1970; Chollet and Ogren, 1975). It appears likely that in this *Dichanthium* dominated grassland, C_4 pathway operates and make it highly productive.

Correlation studies in various structural and functional parameters

Margalef (1965) and McNaughton (1967) after studying various functional and structural attributes of grasslands in California have concluded that 'species diversity is principally a mechanism which generates community stability while dominance is a mechanism which generates community productivity'.

Singh and Misra (1969) and Singh and Ambashta (1975) have further studied these relationship in tropical Indian grasslands and shown that 'Species diversity increases productive efficiency of the ecosystem while dominance makes the system stable, though less efficient for production'. Since these findings of Singh and Misra (1969) and Singh and Ambashta (1975) were contradictory to the observations of McNaughton (1965);and therefore, the relationships among the species diversity, dominance, stability and net production were again considered in the present study for both protected and grazed grasslands.

The results of these correlations in protected and grazed grasslands reveal that dominance is negatively related to diversity ($r = -0.87$, $P < 0.05$ and $r = -0.99$, $P < 0.001$), which confirms the findings of McNaughton (1967), Singh and Misra (1969) and Singh and Ambashta (1975) (Fig. 12a).

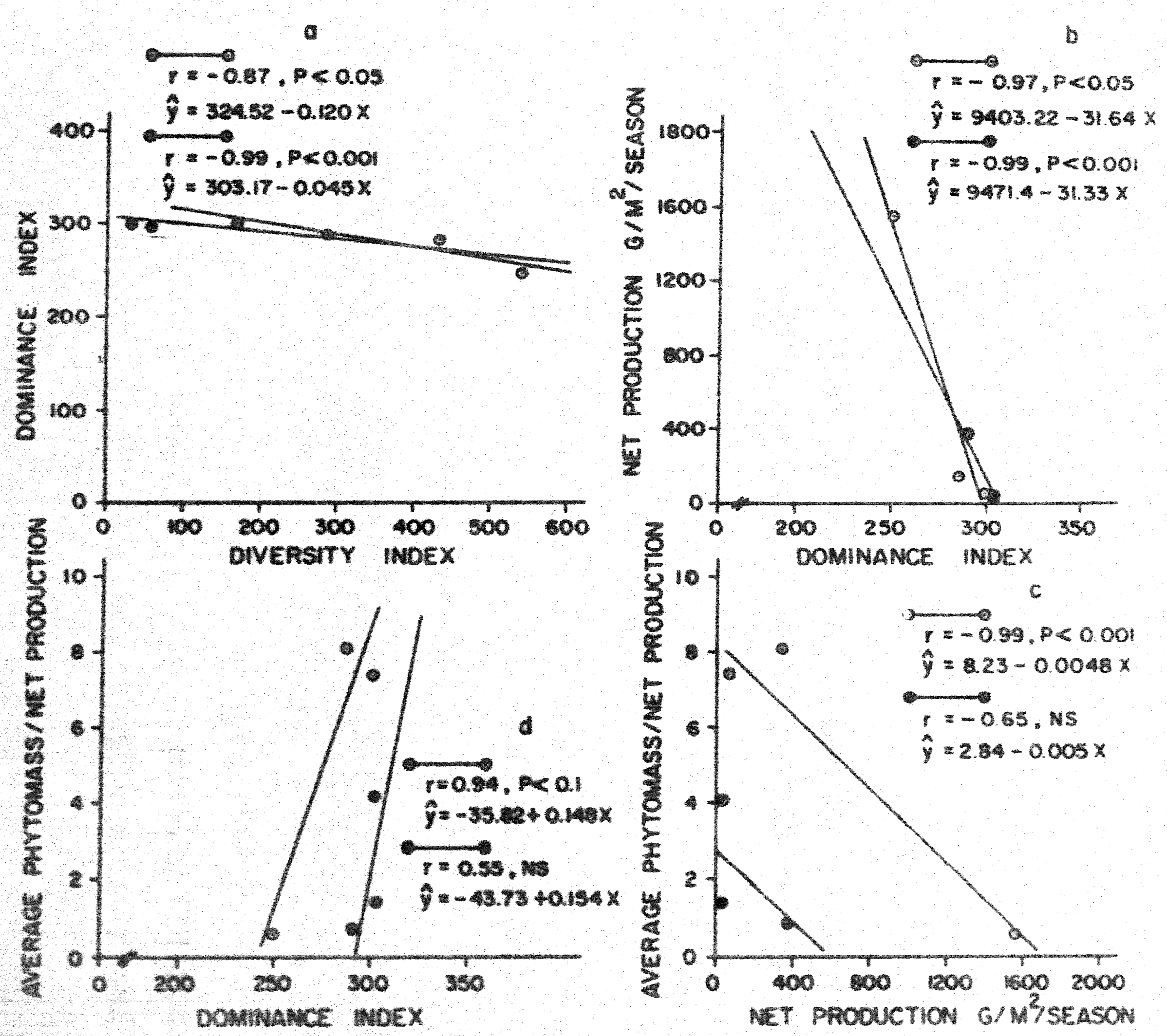


FIG. 12 - RELATIONSHIP BETWEEN SPECIES DIVERSITY, DOMINANCE, STABILITY AND NET PRODUCTION IN o——o PROTECTED STAND, •——• GRAZED STAND

The net community production is also inversely related to dominance index ($r = -0.97$, $P < 0.05$ and $r = -0.99$, $P < 0.001$) (Fig. 12.b). This negative relation indicates a decline in the efficiency of grassland as energy trapping system as has previously been noticed by Singh and Misra (1969) and also is in conformity with the observations of Patten (1963) who stated that 'high productive capacity is associated with high diversity'.

The stability which is reflected by the ratio of above-ground phytomass/net production, is again inversely related to the net production ($r = -0.99$, $P < 0.001$ and -0.65, NS) (Fig. 12.c). This negative relation refers a decline in production with an increase in stability of the community.

Further, stability is directly related to dominance ($r = 0.94$, $P < 0.1$ and $r = 0.55$, NS) (Fig. 12.d), which indicate that increasing concentration of phytomass in species the community becomes more stable.

On the basis of these relationships it can easily be argued that species diversity increases productivity efficiency of the system while dominance makes the system stable, though less efficient for production, thus supporting the findings of Patten (1963), Singh and Misra (1969) and Singh and Ambashta (1975).

SECTION B

LITTER DYNAMICS

To find out an equilibrium between input and output primary production and decomposition are the two fundamental aspects in ecosystem functioning. There is a continuous process of primary production on the one hand and decomposition on the other hand through litter disappearance. Disappearance of dead plant parts in-situ is mainly due to the activity of decomposer organisms and its rate is an important functional aspect of the ecosystem.

The organic matter synthesized during photosynthesis is returned back to the soil in the form of litter, to restore its fertility, through release of nutrients and organic content. During decomposition mineral elements needed for primary production are made available for recycling.

Weigert and Evans (1964) estimated the primary production and disappearance of dead vegetation of an old field in South East Michigan. Madge (1965) worked out leaf fall and litter disappearance in tropical forest. Tripathi (1970) has worked out plant decomposition in a grassland of Varanasi. Gosz et al. (1972) gave a comprehensive account of nutrient release from decomposition of litter. Reice (1974) investigated the seasonal effect on the decomposition of litter.

In India forest leaf decomposition has been studied by Upadhya, 1956; Jain, 1963; Singh, 1968; 1969; Shukla, 1977 and Singh, 1978.

METHODS

The present chapter deals with litter production, decomposition rate and turnover.

Litter collected at monthly intervals from the harvested areas (all the dead fallen parts), kept in polythene bags and oven dried for its dry weight. Its production was calculated by summation of positive increases, following the method as adopted by Singh and Yadav (1974).

Decomposition studies were carried out by 'Paired plot method' of Weigert and Evans (1964), modified by Lomnicki et al. (1968) using the formula.

$$r = \frac{\ln (Wo/W_1)}{t_o - t_1}$$

Where,

r = disappearance rate of dead plant parts in mg/g/day.

Wo = the amount of dead material (h) collected from the fixed quadrats at time t_o in g/m^2.

W_1 = Amount of dead material collected from random matching quadrats at time t_1, minus (h) the amount of dead material added to it during period t_o-t_1 in gm^2.

t_o-t_1 = time interval in days.

For compartmental model disappearance rate was calculated as proposed by Singh and Yadav (1974).

Litter Production

Litter production for the whole study period has been given in Table V 6. It is evident from the table that amount of litter showed a declining trend from June to August with a minimum value of 26.45 g/m^2. After August it increased rapidly with the addition of dead plant parts continuously and attained a maximum value (340.0 g/m^2) of litter phytomass in April, with only a little fall in the value during January and February, indicating a rise in the decomposition rate. Litter fall of dominant species continued upto April while other plants stop in December. Dominant grasses contribute a major portion of litter phytomass. Thus two maxima were observed, one in December and another in April, on protected stand.

Similarly on grazed stand, the same declining trend was obtained from June to August, with a minimum value of 4.92 g/m^2. The production of litter increased after August till December with a maximum value of 133.53 g/m^2, due to addition of dead remains of annuals and tillers of perennials, After December the litter phytomass declined continuously, except March, indicating a rise in decomposition rate. It was observed that annual forbs contribute a major portion of litter phytomass upto December.

Table V 6: Monthly Litter phytomass and production (g/m^2)

Months	Protected stand		Grazed stand	
	Phytomass	Production	Phytomass	Production
June	183.75	-	15.25	-
July	65.45	-118.30	10.85	- 4.40
August	26.45	-39.00	4.92	-5 .93
September	83.64	57.19	25.24	20.32
October	165.42	81.78	41.76	16.52
November	196.97	31.55	86.18	44.42
December	295.80	98.83	133.53	47.35
January	225.02	-70.78	75.30	-48.23
February	153.80	-71.22	40.72	-34.58
March	248.42	94.62	62.32	21.60
April	340.18	91.76	33.88	-28.44
May	265.68	-74.50	27.33	-6.55
June	200.45	-65.23	20.38	-6.95

Total annual production of litter obtained was 455.73 g/m^2, with a rate of 1.24 g/m^2/day. on protected stand and 150.21 g/m^2, with a rate of 0.41 g/m^2/day on grazed stand.

Litter Accumulation (g/m^2)

On a perusal of the Table V 6 it was observed that the period and rate of litter decomposition, which is maximum in rainy season on protected stand but in winter season on grazed stand, may or may not coincide with the period of litter addition or production which is the post winter or early summer.

The production of litter phytomass without destruction leads to litter accumulation in the stands. On protected stand the value of litter accumulation is higher in summer months than rainy and winter, because in summer all the annuals become dead and perennials also by their drying add to the litter phytomass. But on grazed stand litter accumulation was higher in winter season due to death of rainy season annuals. The perennials add very little to litter accumulation due to grazing stress. Thus the period of litter accumulation coincide with the period of litter disappearance on grazed stand.

The values of seasonal accumulation of litter were obtained as 138.97, 130.38 and 186.38 g/m^2 in rainy, winter and summer seasons respectively on protected stand. Annual value was 455.73 g/m^2. While on grazed stand the annual

value was recorded as 150.21 g/m^2 and the seasonal accumulation of litter were 36.84, 91.77 and 21.60 g/m^2 in rainy, winter and summer seasons respectively.

Litter Decomposition

Using Weigert Evans method (1964) monthly rate of litter disappearance has been presented in Table V 7. On perusal of this table it is evident that during rainy season higher rate of disappearance occurred, with a maximum rate(38.0 mg/g/day) in July i.e. 30 days. This increased rate of decomposition was due to higher precipitation, warm temperature and increased activity of microorganisms. After July the rate declined gradually upto May with a minimum value (2.3 mg/g/day) except a very little peak in January (15.0 mg/g/day). Thus during winter season (January and February) a very minor flux in the rate of decomposition of litter phytomass was observed. This little increase was due to winter rains, which resulted in the increase of microbial activity. The fall in temperature and decreased humidity resulted in decreased microbial activity, thus as a result a lower rate of decomposition was observed in the month of December.

A decreasing trend in the rate of litter decomposition was observed throughout summer season (March to May). This is because high temperature, lowest humidity and high wind velocity (except a little rain fall in March/April), considerably decreased the microbial activity. The lowest rate(2.3 mg/g/day)was observed in May.

Table V 7: Litter Disappearance

Weigert Evans method (1964)

Months	Litter Production (g/m^2)		Litter Disappearance (mg/g/day)
	Fixed quadrat	Random quadrat	
June	125.75	152.75	-
July	25.33	65.45	38.0
August	18.24	26.45	37.5
September	75.36	83.64	26.3
October	105.65	155.42	13.3
November	110.80	186.97	10.5
December	190.48	282.80	6.0
January	105.75	225.02	15.0
February	90.38	173.80	8.4
March	170.65	248.42	5.0
April	183.40	355.18	3.7
May	115.80	285.68	2.3
June	105.35	160.45	23.9

Litter disappearance rates for compartmental model have been calculated by another method (Singh and Yadav, 1974) using the difference in litter weight values at the intervals of time. This method also revealed higher rate of disappearance in rainy 157.30 g/m^2 (1.2 $g/m^2/day$) than winter 142.00 g/m^2 (1.1 $g/m^2/day$) and summer 139.73 g/m^2 (1.1 $g/m^2/day$) on protected stand.

In contrast to this on grazed stand, a higher rate of disappearance was observed in winter season 82.81 g/m^2 (0.69 $g/m^2/day$) followed by summer season 51.94 g/m^2 (0.42 $g/m^2/day$) and lower rate of disappearance was recorded in rainy season 10.33 g/m^2 (0.08 $g/m^2/day$).

Table V 8: Seasonal and annual increment (g/m^2) and its rate of production ($g/m^2/day$).

Season	Protected stand		Grazed Stand	
Rainy	138.97	(1.13)	36.84	(0.29)
Winter	130.38	(1.08)	91.77	(0.76)
Summer	186.38	(1.52)	21.60	(0.17)
Annual	455.73	(1.24)	150.21	(0.41)

Values in paranthesës denotes rate of production.

On perusal of Table V 8 it is evident that on protected stand the maximum production was in summer season 186.38 g/m^2

with a rate of 1.52 g/m^2/day. The major contribution appeared to be made by dominant grasses in March and April. Annual production was 455.73 g/m^2 with a rate of 1.24 g/m^2/day.

While on grazed stand the annual increment was recorded as 150.21 g/m^2 with a rate of 0.41 g/m^2/day and the maximum increment was recorded in winter season 91.77 g/m^2 with a rate of 0.76 g/m^2/day, as compared to summer season on protected stand.

Turnover

After litter has fallen to the floor it decays by the action of decomposers and abiotic environment. The rate at which litter decays can be expressed as a constant K or the fraction of litter that decomposes during a unit of time (Jenny et al., 1949; Olson, 1963; Koelling and Kucera, 1965).

Thus the rate of organic matter turnover can be estimated by calculating K constant.

The amount of litter accumulated on the floor X at a given time 't' is described with the relation:-

$$\frac{dx}{dt} = L - K' X$$

Where, L is the annual litter fall and K is the fraction of litter decayed during the specific period. As litter accumulates on the floor, a point is reached when decay equals the production. This condition is called equilibrium or steady state and the relation can be written as:-

$$L = K' X \quad \text{or} \quad K' = \frac{L}{X}$$

Thus turnover rate can be calculated by the above equation. Where, L = Positive increases in litter fall.
X = Average value for the period.

Turnover time

Turnover time is the reciprocal of turnover rate and is expressed as 1/K. The turnover time is the time required to decompose residual litter that is present on the stand floor or X, has also been estimated.

Table V 9: Turnover of organic matter (Litter)

	Turnover rate 'K'		Turnover time 1/K	
	Per year	10^{-2}/day	Year	Days
Protected stand	2.42	0.66	0.413	152
Grazed stand	3.50	0.95	0.285	105

Turnover rate in the case of grazed stand was higher as compared to protected stand. Similarly less time is required for complete replacement of litter in grazed stand than protected stand.

DISCUSSION

Litter production and disappearance are highly affected by the seasons. The month of April in summer recorded the maximum amount of litter on protected stand and in December on grazed stand. This is because of rapid conversion of plants and plant parts into dead parts which are fallen to the ground in the preceding months. In the months of June, July and August there is a rapid decomposition of litter, which usually start with the onset of monsoon, that is when the moisture is abundant the litter phytomass fast declines. At the end of the monsoon the litter phytomass again started increasing gradually, it was due to the death of the rainy season annuals, which is at faster rate than decomposition rate. Choudhary (1967) and Tripathi (1970) observed the same trend at Varanasi.

Decomposition proceeds with a fast rate in rainy season and slowly in winter and summer respectively on protected stand. This high rate of disappearance in rainy season is due to high moisture content and warm temperature, which favourably increases the growth of microbes and their activities. During winter the rate of disappearance decreased, this may be due to fall in temperature resulting into lesser microbial activity. In summer the microbial activity becomes limited due to high temperature and less moisture, resulting in the decrease of litter decomposition rate. In contrast to this on grazed stand the litter

disappearance was recorded maximum in winter season and lowest in rainy season. This indicates that although microbial activity is pronounced in rainy season, Litter disappearance is limited by the amount of substrate (dead material) available. It was also recorded here that in summer season more litter disappeared than was produced in that season. These findings are in agreement of Singh and Yadav (1974).

Litter disappearance rates have also been calculated by using Weigert and Evans method (1964) on monthly basis for protected stand, which clearly indicated a faster rate of disappearance in rainy season than winter and summer season. The periodical rate of disappearance obtained by Weigert and Evans method, when treated statistically with climatic attributes (i.e. precipitation, temperature and humidity), a significant positive relationship was obtained for rate of disappearance with relative humidity ($r = + 0.85$, $P < .001$) and rainfall ($r = + 0.81$, $P < .001$) whereas an insignificant value of correlation coefficient ($r = + 0.29$, NS) was computed with atmospheric temperature (Table V 10 and Fig. 13a,b). These values of correlation coefficient suggest that the rate of litter disappearance increases with an increase in the relative humidity and rainfall while temperature had no effects in this respect. It may easily be explained as the maximum rates of litter disappearance were recorded during rainy months, when the climate of the study area remains warm and humid without sharp fluctuations in atmospheric temperatures as has also been discussed earlier by Naik and Mishra (1976).

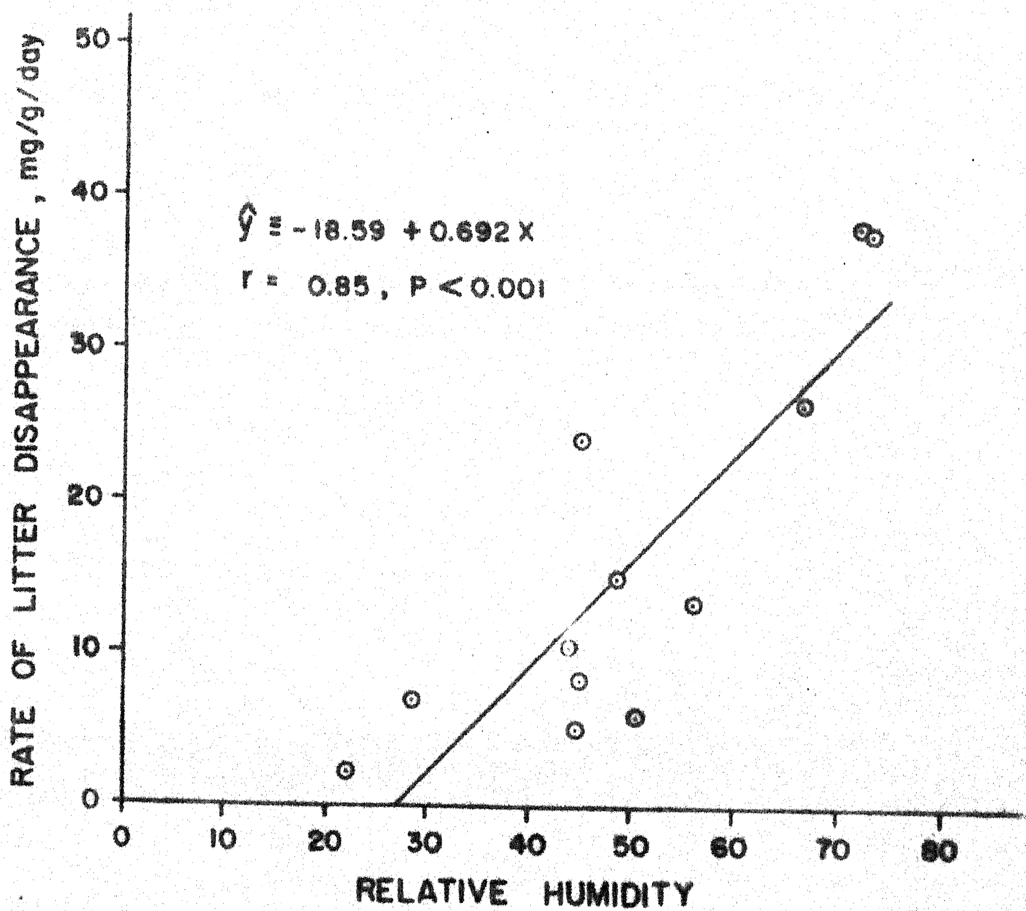


FIG. 13 a – RELATIONSHIP BETWEEN RATE OF LITTER DISAPPEARANCE AND RELATIVE HUMIDITY.

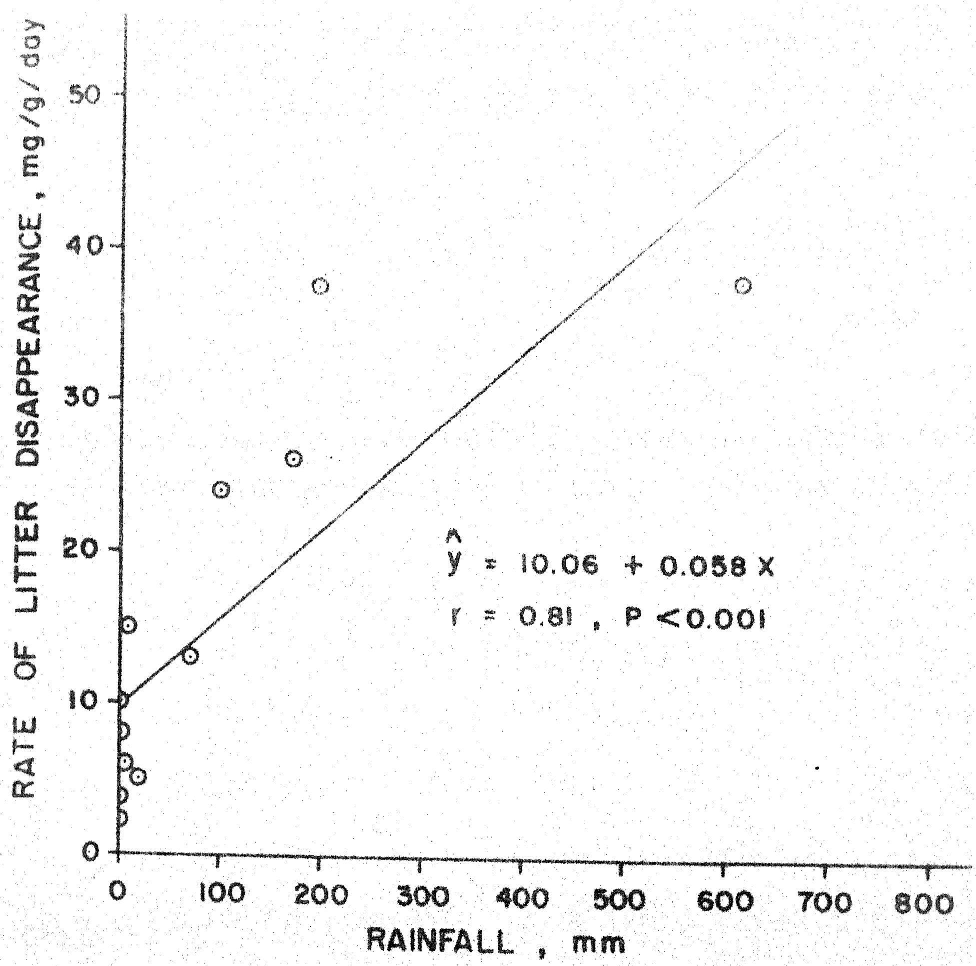


FIG. 13 b - RELATIONSHIP BETWEEN RATE OF LITTER DISAPPEARANCE AND RAINFALL

Table V 10: Correlation coefficient and regression equation for climatic attributes and rate of disappearance.

Attributes	Regression equation	Correlation coefficient 'r'
Relative humidity and rate of disappearance	$\hat{y} = -18.59 + 0.692\,x$	0.85 **
Rainfall and rate of disappearance	$\hat{y} = 10.06 + 0.058\,x$	0.81 **
Temperature and rate of disappearance		0.29

** Significant at 0.001 P

For compartmental model, litter disappearance rates have been calculated, seasonally as well as annually by the method of Singh and Yadav (1974), using the difference in litter weight values at two intefvals for both the stands.

The first method revealed litter disappearance in a natural condition of the vegetation, while the second method is purely artificial.

Turnover rate K' calculated as per Koelling and Kucera (1965), was obtained as $2.42/y^{-1}$ and $0.66^{-10^{2}}$/ day, while turnover time 1/K, the time required to decompose the residual litter, was 0.413 yr or 152 days for protected stand, which is lower to that of grazed stand with a rate of $3.50/y^{-1}$ and $0.95^{10^{-2}}$/day and time required was 0.285 yr or

105 days. Thus showing a fast turnover of litter phytomass on grazed stand.

Annual balance of production and decomposition

Seasonal and annual values of litter production and decomposition have been represented in a model form, which gives a comprehensive account of balance between production and disappearance of litter phytomass of a community (Model 1A and B).

On protected stand, total annual litter production was 455.73 g/m^2 (1.24 $g/m^2/day$), out of which rainy season accounted 31%, winter season 28% and summer season 41%.

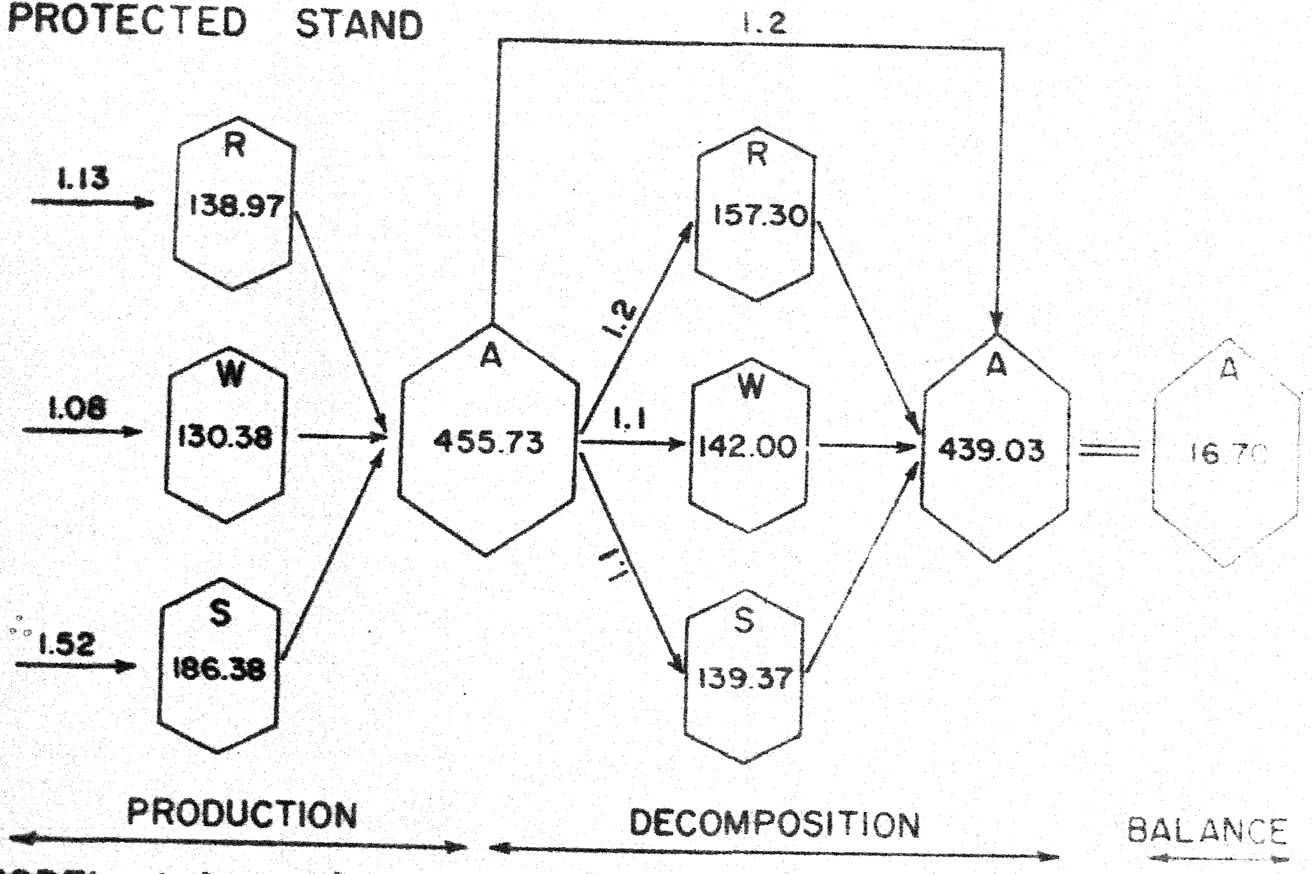
Similarly on grazed stand, total annual litter production was 150.21 g/m^2 (0.41 $g/m^2/day$), out of which rainy season accounted 24.5%, winter season 61.1% and summer season 14.4%.

The thin vegetation, exposed condition and blowing action of wind may be responsible for such a decrease of litter on grazed stand.

Total annual disappearance recorded, on protected stand, was 439.03 g/m^2 (1.20 $g/m^2/day$). Out of the total amount of litter disappeared, the seasonal percentage was 36%, 33% and 31% in rainy, winter and summer respectively.

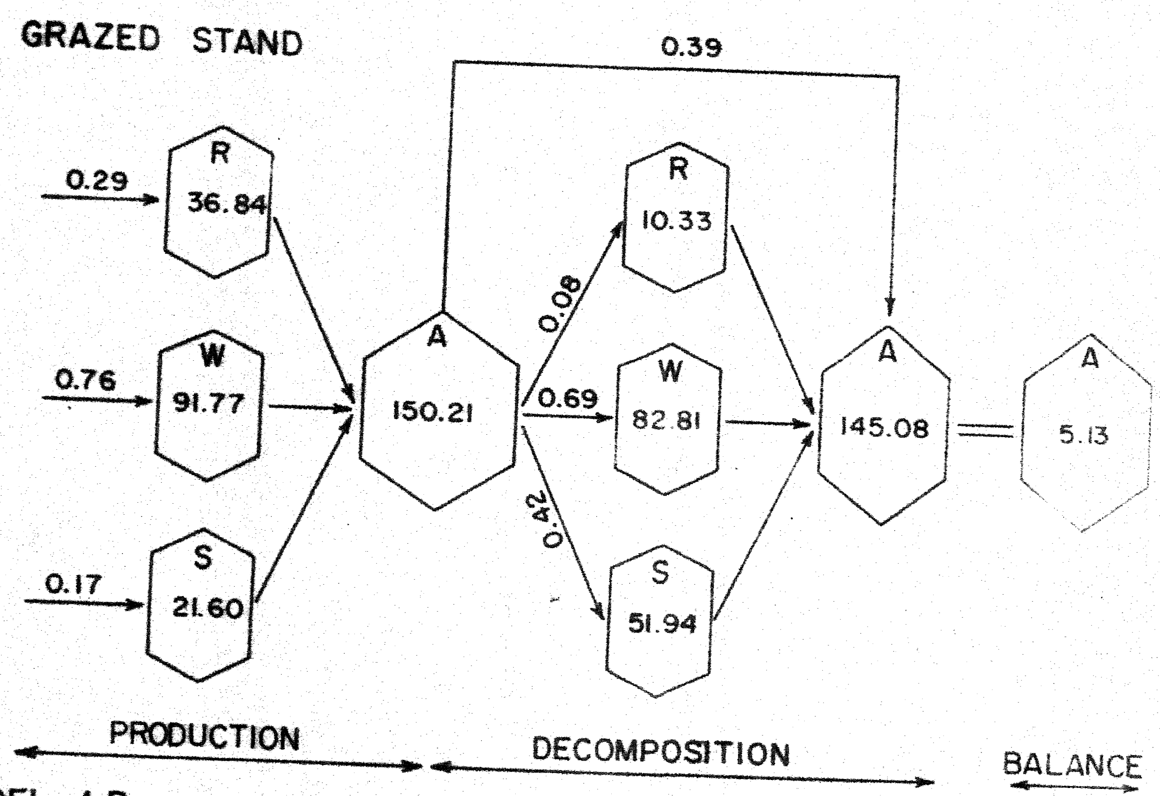
While on the grazed stand total annual disappearance was 145.08 g/m^2 (0.39 $g/m^2/day$), out of which rainy season share was 7.1%, winter season 57.1% and summer season 35.8%.

PROTECTED STAND



MODEL. 1 A -

LITTER PRODUCTION AND DECOMPOSITION BALANCE MODEL



MODEL. 1 B -
LITTER PRODUCTION AND DECOMPOSITION BALANCE MODEL

The high percentage in summer might be due to unusual rain in March and due to start of the monsoon in the last week of June, as well as due to greater litter phytomass accumulation in the protected stand during early summer i.e. March/April. In tropical countries like India, humidity is a more important factor in controlling the rate of decomposition. About 95% of the total litter production disappeared in a year on protected stand and 96% on grazed stand.

The total amount of litter disappeared annually and its percentage to aboveground net production could be compared with the reports of other tropical grasslands by different authors as shown in Table V 11. On perusal of this table, it is concluded, that in the present investigation a lower percentage of amount of litter disappeared as compared to other reports, except Trivedi (1976), who reported a still lower percentage. This might be due to the difference in the methods of calculations. Usually, Golley's method (1965) gives higher values as obtained by Mall _et al_., 1973; Gupta, 1976; Billore, 1978; and Agnihotri, 1979 etc.

Table V 11: Amount of Litter Disappeared and its percentage of A.N.P.

Community		Place	L.D. $g/m^2/yr$	A.N.P. (in %)	Author	Year
<u>Sehima</u>	-	Ratlam	253.3	58	Mall <u>et al</u>.	1973
Mixed	-	Kurukshetra	923.0	38	Singh and Yadav	1974
<u>Heteropogon</u>	-	Sagar	499.6	67	Dakwale	1975
<u>Themeda</u>	(Protected)	Jhansi	466.4	49	Gupta	1976
<u>Themeda</u>	(Disturbed)	Jhansi	391.2	44	Gupta	1976
<u>Sehima</u>	-	Jhansi	235.0	15	Trivedi	1976
<u>Dichanthium</u>	-	Dhakarwara	160.0	19	Trivedi	1976
<u>Cenchrus</u>	-	Vijaipur	278.3	37	Pandeya <u>et al</u>.	1977
<u>Iseilema</u>	(Grazed)	Ujjain	273.8	80	Billore	1978
<u>Dichanthium</u>	(Protected)	Ujjain	588.7	65	Billore	1978
<u>Bothriochloa</u>	(Grazed)	Mandla	390.0	98	Agnihotri	1979
<u>Bothriochloa</u>	(Protected)	Mandla	710.0	81	Agnihotri	1979
<u>Dichanthium</u>	(Protected)	Orai	439.0	25	Present study	1980
<u>Dichanthium</u>	(Grazed)	Orai	145.08	32	Present study	1980

SECTION C

DRY MATTER DYNAMICS

Net Accumulation, Transfer and Disappearance of organic matter

Accumulation of phytomass of different components have been calculated separately for the three seasons and on an annual basis in Section A. Details of the data on litter production are described and discussed in this chapter under Section B.

The litter disappearance values have been calculated by the method described by Singh and Yadav (1974).

L.D. = (Initial litter+Litter production)-(Litter at the end)

The underground disappearance was calculated by the summation of negative changes in the underground phytomass on successive sampling dates (Singh and Yadav, 1974). Total disappearance is the sum of litter disappearance and underground disappearance.

Dynamic behaviour of the system has been presented through compartment model. Each vegetational component has been shown in separate compartment with its own rate of output and input. Values on arrows represent the flow rates on average per day basis, and inside the rectangular compartments the standing state of phytomass in g/m^2, on an annual

and seasonal basis. Golley (1965) expresses that average standing crops are not as informative as the transfer rates between compartments, since they are only an approximate measure of the storage capacity.

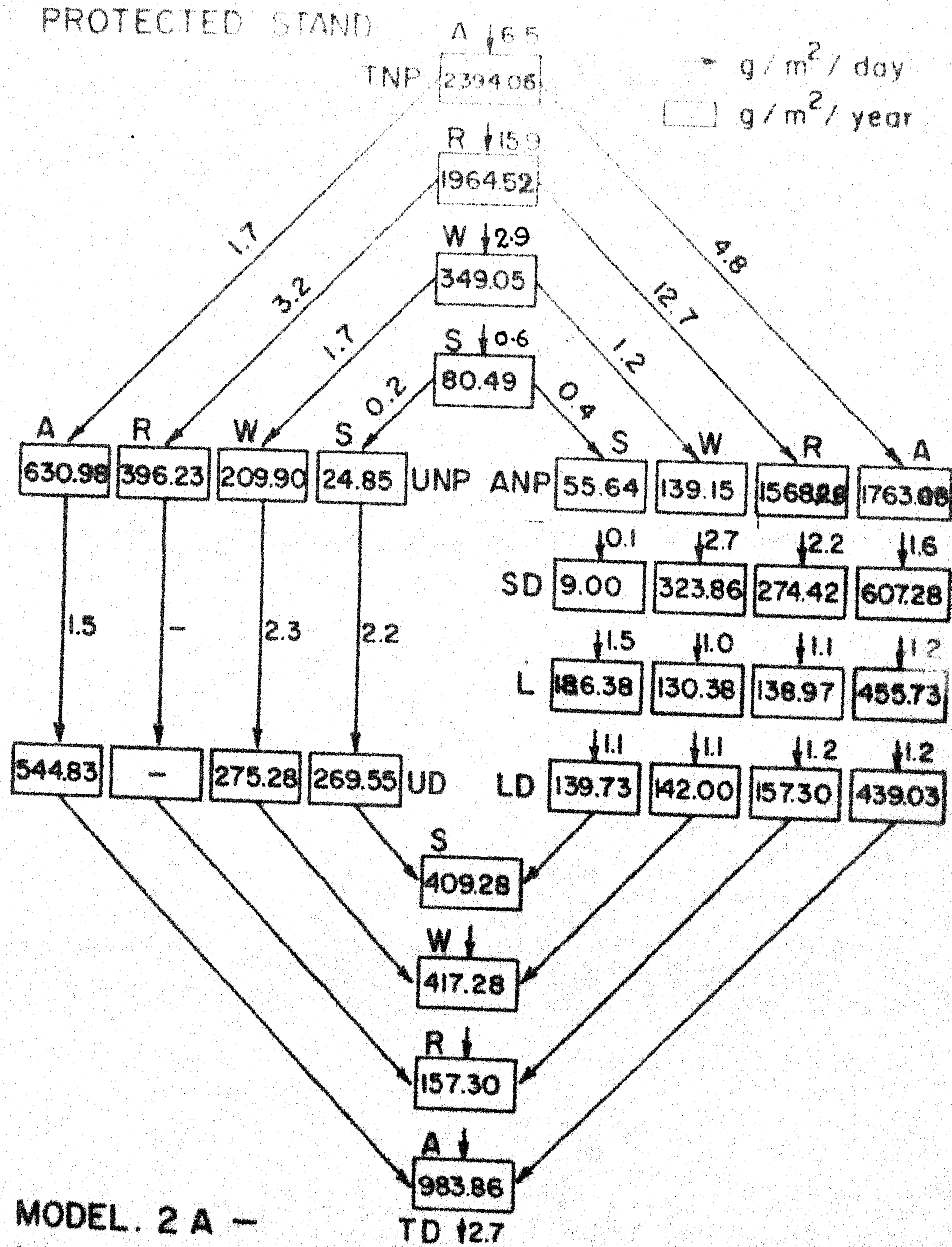
Seasonal/Annual Accumulation and Disappearance rate

The net accumulation and disappearance rate on per day basis are shown in Model 2A,B for both the stands.

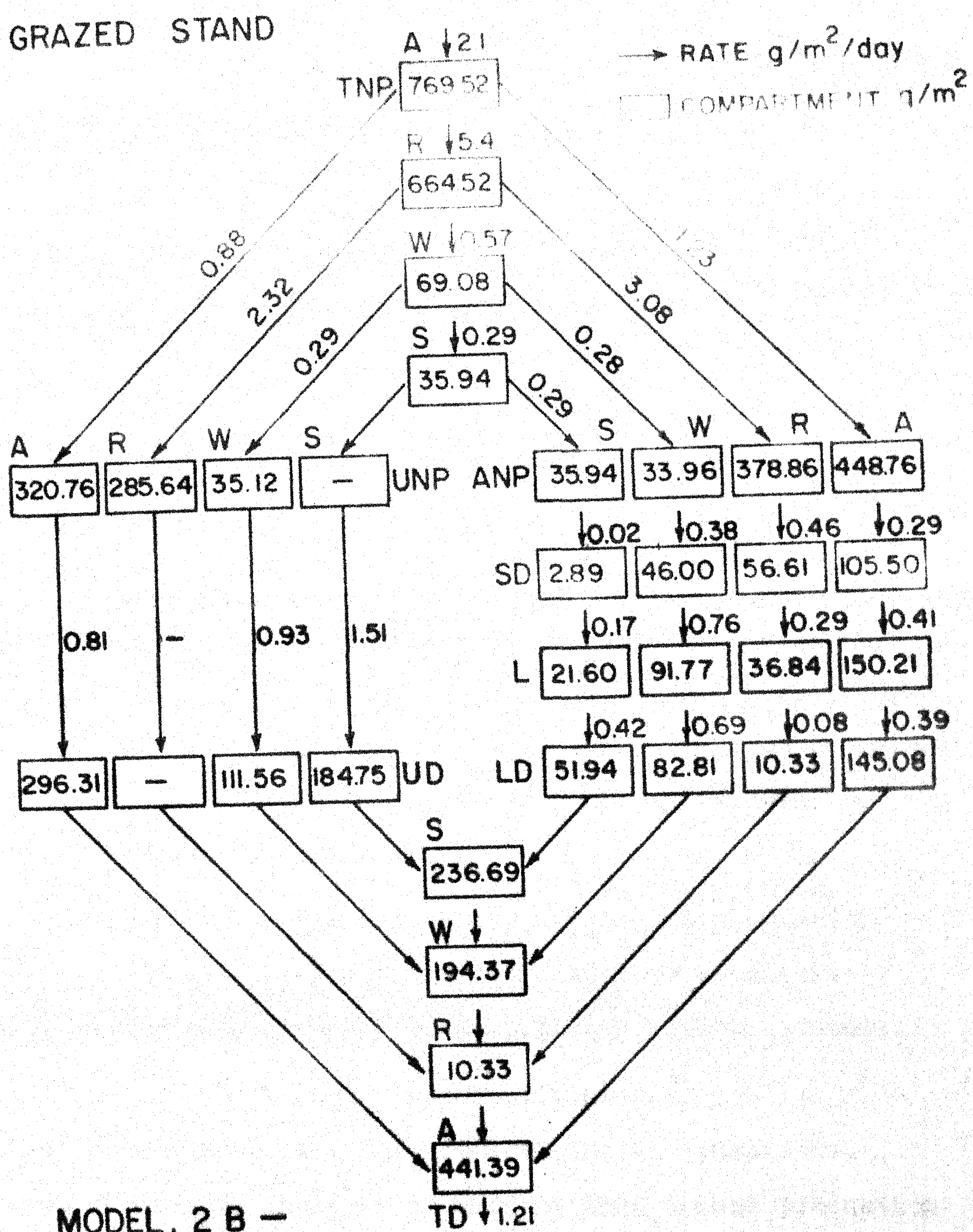
Out of the total net production (T.N.P.) the maximum quantity is shared by aboveground net production (A.N.P.) in the rainy season and minimum in the summer season. The same trend is followed in the transfer from T.N.P. to underground compartment, viz. maximum rate of transfer is observed in rainy season and minimum in summer season, while no transfer from T.N.P. to underground net production (U.N.P.) is recorded on grazed stand in summer season.

The rate of transfer of organic matter from A.N.P. to standing dead (S.D.) compartment is high in winter and low in summer on protected stand, while it is high in rainy season on grazed stand due to progressive death of the annuals and grazing affects.

The rate of accumulation of organic matter in litter compartment is maximum in summer might be due to rapid transfer of dead matter even of previous season and the lowest in winter on protected stand, but on grazed stand maximum is obtained in winter and minimum in summer.



MODEL. 2 A – NET PRODUCTION, ACCUMULATION AND DISAPPEARANCE RATES.



MODEL. 2 B —

NET PRODUCTION, ACCUMULATION AND DISAPPEARANCE RATES.

The rate of transfer from litter compartment to litter disappearance is maximum in rainy season closely followed by winter and summer season on protected stand, but the litter to litter disappearance transfer is found maximum in winter season followed by summer season and rainy season on grazed stand.

Transfer rate of underground net production to underground disappearance, on protected stand, is maximum in winter closely followed by summer, while no disappearance rate is recorded in rainy season. But on grazed stand maximum rate was obtained in summer followed by winter season and no disappearance in rainy season.

The rate of accumulation of organic matter in the total net production on per day basis is found to be 6.5 $g/m^2/day$ and 2.1 $g/m^2/day$ and the rate of total disappearance of organic matter is found 2.7 $g/m^2/day$ and 1.2 $g/m^2/day$ on both the stands respectively.

Thus about 41% and 57% of the net annual production (T.N.P.) is released from different compartments and is available for heterotrophic consumption on both the stands.

A comparative account of dry matter dynamics is presented in the Table V 1.2, of some Indian grasslands. On perusal of this table it is evident that annual production and disappearance of protected grassland is quite comparable to the reports of Billore (1978) for Ujjain but lower to that of Singh and Yadav (1974) for Kurukshetra grassland. The

Table V 5: Comparative account of Net production of Indian grasslands (g/m^2)

Grassland		Place	A.N.P.	U.N.P.	T.N.P.	Author	Year
Dichanthium	-	Varanasi	515.0	308.0	823.0	Singh	1968
Dichanthium	(Protected)	Varanasi	1358.7	-	1358.7	Maurya	1970
Heteropogon	(Protected)	Sagar	1494.0	1284.2	2778.2	Jain	1971
Dichanthium	(Seasonally harvested)	Sagar	1694.0	662.4	2356.4	Jain	1971
Dichanthium	(Disturbed)	Sagar	596.0	937.0	1533.0	Jain	1971
Tropical	-	Varanasi	2218.0	1377.0	3595.0	Singh	1972a
Vetiveria	(Grazed)	Varanasi	-	-	1774.8	Singh	1972b
Heteropogon	(Protected)	Varanasi	-	-	4220.0	Singh	1972
Dichanthium	(Protected)	Varanasi	504.0	551.0	1055.0	Choudhary	1972
Heteropogon	(Protected)	Delhi	798.0	532.0	1330.0	Varshney	1972
Sehima	-	Ratlam	429.2	417.0	846.2	Billore	1973
Dichanthium	-	Ujjain	564.0	425.0	989.0	Misra	1973
Bothriochloa	(Protected)	Ambikapur	874.0	976.0	1850.0	Naik	1973
Bothriochloa	(Grazed)	Ambikapur	314.0	592.0	906.0	Naik	1973
Mixed	-	Kurukshetra	2407.0	1131.0	3538.0	Singh and Yadav	1974
Heteropogon	(Protected)	Sagar	745.0	872.0	1617.0	Dakwale	1975
Themeda	(Grazed)	Jhansi	860.0	502.5	1383.0	Gupta	1976
Themeda	(Protected)	Jhansi	945.9	439.2	1385.1	Gupta	1976
Sehima	(Protected)	Jhansi	1504.0	1166.1	2670.1	Trivedi	1976
Dichanthium /Iseilema	(Grazed)	Dhakarwara	841.8	773.2	1615.0	Trivedi	1976
Cenchrus	(Grazed)	Rajkot	244.0	7788.0	8032.0	Pandeya *et al.*	1977
Iseilema	-	Ujjain	453.5	710.0	1163.5	Billore	1978
Dichanthium	(Protected)	Ujjain	1404.9	626.0	2033.9	Billore	1978
Bothriochloa	(Grazed)	Mandla	440.6	615.5	1056.1	Agnihotri	1979
Bothriochloa	(Protected)	Mandla	875.5	788.0	1663.5	Agnihotri	1979
Dichanthium	(Protected)	Orai	1763.1	630.9	2394.0	Present study	1980
Dichanthium	(Grazed)	Orai	448.8	320.7	769.5	Present study	1980

values of the grazed grassland of the present investigation could also be compared with the grazed grassland of Ujjain (Billore, 1978). Exceptionally high values have been recorded for Vasad and Vijapur grasslands by Pandeya _et al_. (1973).

Thus it can be concluded that rate of production and disappearance depends on the climatic conditions of the area and other biotic interferences.

System Transfer Function

A system may be defined as a collection of components arranged and interconnected in a definite way (Mall _et al_., 1973). As per Sims and Singh (1971) the system transfer functions reflects the orientation of the functioning of an ecosystem in space and time. System dynamics pertains to the rates of input to the system, transfer within the system internal dynamics and loss from the system, out-put. Grodins (1963), Golley (1965) have defined system transfer function as the quantity by which the system block multiplies the input to generate the output or alternatively, as the ratio of output to input. This relation may be written by the following equation:-

$$O = \left[\frac{I}{K}\right] I \qquad \text{or} \qquad \frac{O}{I} = \left[\frac{I}{K}\right]$$

Where, O = output, I = Input and

$\frac{I}{K}$ = System transfer function

In the present investigation, system transfer function between flow rates of different compartments have been estimated to show intricate behaviour of each compartment. The system transfer functions (S.T.F.) have been calculated seasonally and annually using the compartment values in the models for both the stands, and presented in the Table V 13.

The values in the table indicate that transfer functions of T.N.P. to A.N.P. on protected stand is maximum 79% in rainy season and minimum 39% in winter season. The intermediate value of 69% is obtained in summer season. While on grazed stand T.N.P. to A.N.P. is maximum in summer 100% followed by rainy 57% and minimum in winter 49%. This higher value in summer than winter on grazed stand is obviously due to the fact that there is no transfer from T.N.P. to U.N.P. during this season.

The transfer function from T.N.P. to U.N.P. is found to be lesser than A.N.P. and maximum value of 60% and 50% are obtained in winter season on the two stands. Thus the cool and dry period seems to be more favourable for accumulation underground.

On an annual basis the transfer function from T.N.P. to A.N.P. on both the stands are higher 74% and 58% in comparison to T.N.P. to U.N.P. 26% and 42%. This clearly indicate higher organic matter accumulation in aboveground parts than underground parts.

Table V 13: System Transfer Function of Dry matter Dynamics

Component	Protected stand				Grazed stand			
	Seasonal			Annual	Seasonal			Annual
	Rainy	Winter	Summer		Rainy	Winter	Summer	
T.N.P. to A.N.P.	0.79	0.39	0.69	0.74	0.57	0.49	1.00	0.58
T.N.P. to U.N.P.	0.20	0.60	0.30	0.26	0.42	0.50	-	0.42
A.N.P. to S.D.	0.17	2.30	0.16	0.34	0.15	1.35	0.02	0.24
S.D. to L.	0.50	0.36	18.48	0.69	0.65	1.99	7.47	1.42
A.N.P. to L.	0.08	0.78	2.69	0.22	0.09	2.70	0.60	0.33
L. to L.D.	1.13	1.09	0.74	0.95	0.28	0.90	2.40	0.96
U.N.P. to U.D.	-	1.31	10.84	0.86	-	3.17	-	0.92
T.N.P. to T.D.	0.07	1.10	5.20	0.41	0.01	2.81	6.58	0.57

In the present investigation, greater aboveground directed productivity during the wet season and greater underground directed productivity during cool dry period was observed. Sims and Singh (1971) hypothesized that higher underground net productivity at lower temperature, may result from enhanced downward translocation of the assimilates with lower respiratory loss or changes in the botanical composition.

The transfer function from A.N.P. to S.D. (standing dead) are maximum 230% and 135% in winter season on both the stands and minimum 16% and 02% in summer season. This high transfer in winter is due to the fact that all the rainy season annuals die and become standing dead in winter season. The perennials also due to drying and withering of their tillers add to the standing dead phytomass of winter season. Hence S.D. is more or less three times greater than A.N.P. in winter on both the stands. The minimum percentage from A.N.P. to S.D. in summer is due to the fact that a little transfer from the aboveground parts to standing dead takes place during summer. On an annual basis the transfer from A.N.P. to S.D. are 34% and 24% on the two stands respectively.

The accumulation of organic matter in the litter (L) compartment is maximum 1848% on protected stand and 747% on grazed stand in summer season through standing dead compartment. This is obviously due to the fact that standing dead of

previous seasons too are added to the litter compartment. Transfer from S.D. to L are 69% and 142% annually, or 69% of S.D. found its way into the L compartment on protected stand and more litter produced than S.D. on grazed stand might be due to direct addition of phytomass as a result of grazing.

The litter to litter disappearance (L.D.) transfer on protected stand is highest in rainy season 113%, showing a faster rate of disappearance, more than the amount of litter produced in the respective season. High moisture and warm temperature of rainy season resulted in a rapid decomposition of litter. In winter season also the rate of decomposition is quite high 109% indicating that L.D. takes place in the presence of little moisture if the temperature is not very low. According to Singh and Yadav (1974) temperature never being too low, decomposition proceeds at a faster rate because of the abundance of substrate for microbes. In summer the L.D. is also quite high 74% compared to other reports of grasslands. This is because of the fact that March and June experienced a good rain and L.D. depends on the availability of the substrate also.

In tropical countries like India humidity is a more important factor in controlling the rate of decomposition. The high rate of L.D. in summer also supported the observation of Clark and Colemn (Reuss, 1971) that even small amount of precipitation during summer cause several fold increase in microbial activity.

Similarly on grazed stand, higher percentage of transfer from L to L.D. was observed in winter and summer as compared to rainy season. The lower percentage of L to L.D. in rainy season is owing to the fact that grazing makes the surface barren and due to high velocity of wind in summer months the litter phytomass are blown away from these barren areas. The annual L.D. comes to 95% and 96% on the two stands respectively.

In the case of transfer from U.N.P. to U.D. the summer season shows the maximum disappearance. This high rate of disappearance is due to negative phytomass values during summer months and due to some soil moisture which may favour the microbial activity.

Thus it is observed that transfer of L to L.D. and U.N.P. to U.D. is almost at the same percentage viz. 95% and 86% on protected stand and 96% and 92% on grazed stand.

The transfer function from total net production (T.N.P.) to total disappearance (T.D.) for the whole year is 41% and 57% for both the stands and rest remain as standing dead and litter in the vegetation and carried over to next year.

A comparative account of S.T.F. of different Indian grassland communities is given in Table V 14.

It is evident from the table that most of the transfer functions of the present investigation except with few differences are favourably comparable with other tropical

Table V 14: System Transfer Functions of some tropical grassland communities (1971-80)

Components	Sims & Singh 1971 U.S.A.	Misra 1973 Ujjain	Billore 1973 Ratlam	Singh & Yadav 1974 Kurukshetra	Gupta 1976 Jhansi	Trivedi 1976 Jhansi	Billore 1978 Ujjain	Agnihotri 1979 Mandla	Present investigation: Protected stand 1980 Orai	Present investigation: Grazed stand 1980 Orai
T.N.P. to A.N.P.	0.43	0.57	0.50	0.68	0.68	0.56	0.69	0.52	0.74	0.58
T.N.P. to U.N.P.	0.57	0.42	0.49	0.32	0.32	0.43	0.31	0.48	0.26	0.42
A.N.P. to S.D.	0.59	0.74	0.96	0.54	1.99	0.27	0.81	0.80	0.34	0.24
S.D. to L.	1.00	0.82	0.85	0.76	1.00	0.70	0.57	0.81	0.69	1.42
A.N.P. to L.	-	-	0.03	0.41	-	0.19	0.19	0.19	0.22	0.33
L. to L.D.	1.44	0.62	0.71	0.94	1.00	0.81	0.64	0.95	0.95	0.96
U.N.P. to U.D.	0.90	0.76	0.59	1.05	1.24	0.67	0.81	0.75	0.86	0.92

grasslands. The value of T.N.P. to A.N.P. ranged from 39 to 69% in Indian grasslands but in the present investigation this value is recorded as 74% and 58% for both the stands. These higher values clearly indicate more aboveground directed productivity than underground. Pandeya _et al_. (1973) obtained a very low percentage (0.03%) and explained it on the basis of xeric condition. It was observed that though the amount of litter collected on protected stand was more as compared to grazed stand but the percentage of loss is more on grazed stand. The percentage values are closer to that of Naik (1973, Ambikapur) and Singh and Yadav (1974, Kurukshetra). Total disappearance was found as 41% and 57% of the total net production. These are slightly lower to other reports. The slight variation in different components S.T.F. may be due to the differences in climatic, edaphic and floristic characters. Thus it can be concluded that grassland ecosystem functioning directly depend on the seasonality as revealed by S.T.F.

SECTION D

CONSUMERS AND SECONDARY PRODUCTIVITY

Insect cause a considerable problem in the tropics with the grasslands; these insect populations are particularly conducive to instability (Van Dyne et al., 1978). According to Milner et al. (1968), the invertebrate herbivores of these tropical grasslands are important consumers and they remove a considerable amount of organic matter, which is not reflected in the estimation of aboveground phytomass by harvest method of an ungrazed ecosystem. Therefore, they suggested a semiquantitative estimation of major invertebrate groups of these grasslands.

Biomass studies

In the present study most of visible types of insects and other macroorganisms were collected with the help of insect net during the day upto maximum possible extent. Estimation of certain nocturnal insects, which defoliate plants, with a light trap could not be done. The macroorganisms and insects were brought to the laboratory, identified groupwise and oven dried to get their dry weight. The results are presented in the Table V 15.

On perusal of the table it can be concluded that the secondary producers belonging to group Orthoptera could be seen to survive throughout the study period. On the onset

Table V 15: Monthly records of biomass of secondary producers (g/m^2)

Consumers/ Secondary producers	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Orthoptera	2.55	6.06	7.48	2.44	1.43	1.45	0.89	0.30	1.01	0.65	0.58	0.36	2.82
Hemiptera	-	1.65	3.73	0.83	0.04	0.30	0.06	0.04	0.05	0.01	-	-	-
Miscellaneous group	-	0.87	1.39	0.98	0.43	0.14	0.11	0.04	0.05	0.02	-	-	-
Total phytomass	2.55	8.58	12.60	4.25	1.90	1.89	1.06	0.38	1.11	0.68	0.58	0.36	2.82

of monsoon in the last week of June and July, after a flux of new growth in the vegetation, the egg laying process started and within a short time a good growth of secondary producers was observed. The main groups were Orthoptera and Hemiptera Other smaller insects and macroorganisms were placed in miscellaneous group. Mathur et al. (1956) recorded 27 Hemipteran insects which are mostly defoliators.

The Orthopterans are main contributors of the total consumers biomass. Concomittent with the mateorological changes the biomass started increasing in July with a maximum of 12.60 g/m^2 in August, when conditions are optimum. After August the value declined throughout, except a very minor increase in February after winter rains. In winter low temperature was the main factor for decline in the populations of individuals. The minimum value was obtained in May. Thus two peaks in the secondary productivity were obtained during the period of study.

It was observed by Mathur et al. (1956) that high relative humidity and moderate temperature are suitable for the activity of the most of the Orthopterans. The same is found true in the present investigation.

Therefore, it is concluded that the value of aboveground phytomass would have been more, if there would have been no consumption by these herbivores and consequently the aboveground production would have been more.

Thus the seasonality of climate together with the diversity in vegetation create a favourable environment for the biota in this grassland.

Livestock and Herbage removal

The grazing by the animals of a grassland must be within the carrying capacity of that land. Kumar (1946), Prasad (1956) gave the carrying capacity of forest grassland in terms of rain fall. According to them 1.6 ha/cow unit has been considered as conservative grazing. Upadhyay *et al.* (1971) reported carrying capacity of a *Dichanthium* dominated grassland as 6.2 sheep/ha or 1.24 cow/ha. But in natural practice number of grazers per hectare exceeds very much to that of average carrying capacity of that land, resulting into large herbage intake by these grazers.

Different types of grazers visit the study stand everyday. Therefore, a possible survey of these large grazers was done seasonally and an average number of livestock visiting the grassland is shown in this table.

Table V 16: Average number of chief grazers visiting the grazing land. (1977-78)

Cattle	Buffaloes	Goats	Sheep	Total livestock
228	103	75	139	545

According to Milner et al. (1968) estimation of the amount of organic production removed by large grazing animals of the area is of significant importance in an ecosystem. They have suggested formulae for calculation of net herbage intake based on the monthly phytomass data of the grazed and ungrazed ecosystems.

I. Herbage intake = Weight of herbage inside the enclosure − Weight of herbage outside the enclosure

II. Another formula recommended by them was originally proposed by Linehan et al. (1952) for heavily grazed land open for long time.

$$\text{Herbage intake} = C - f \times \frac{\log d - \log f}{\log c - \log f}$$

Where,

c = herbage weight at the previous cut outside.

f = herbage weight at this cut outside

d = herbage weight at this cut inside.

Mehta (1977) modified this formula in a simple way to get net removal of aboveground phytomass by the grazing animals.

Net herbage intake = Total positive increase in live (green) of all species inside at time t. − Total positive increase in live (green) of all/sp. outside at time t.

In the present investigation the following methods have been employed to calculate the net herbage intake.

		Protected stand g/m^2	Grazed stand g/m^2	Herbage intake g/m^2
I.	Annual average of total aboveground standing crop (live and standing dead).	829.02	152.81	676.21
II.	Positive increases in standing live phytomass only.	1349.69	391.23	958.46
III.	Positive increase in standing live phytomass plus concomittent increases in standing dead and litter component viz. A.N.P.	1763.08	448.76	1314.32

The first method is under estimation, while third method will be over estimation. Therefore, the average of the two values have been taken. This value is almost equal to the value obtained by second method.

Average value of 1st and 3rd method = 995.26 g/m^2.

Thus it is concluded that net herbage removed from grazed stand by the grazing livestock will be approximately 995.26g/m^2 (2.73 g/m^2/day), which is about 56% of the aboveground net production of protected stand. This observation supported

the findings of Odum (1966), who mentioned that in a heavily grazed grassland, 50% or more of annual net production may pass on to grazing animals.

Impact of Grazing on the community

It is difficult to understand the impact of grazing unless the various functional attributes such as growth and primary production are considered because the impact of grazing was more than just herbage removal (Ronald, 1978).

The present investigation clearly revealed this impact on aboveground and underground phytomass, its ratio and net primary production.

Aboveground phytomass showed peak value in October on protected stand and in September on grazed stand (Table IV 2 a,b). Similarly, underground phytomass showed peak values in November on protected stand and in October on grazed stand. Under the same climatic conditions, the occurrence of peak values in different months on the two stands clearly indicate grazing influence on their phytomass values.

Many workers (Pearson, 1965; Singh, 1968; Jain, 1971; Naik and Mishra, 1974; Gupta, 1976; Pandeya et al., 1977; Ronald, 1978; and Billore, 1978) have given due importance to the U.G./ A.G. phytomass ratio, because it gives an idea of plant response under grazing conditions. They have

observed an increase in this ratio as a result of grazing. The values obtained in the present investigation also supported their findings. The maximum ratio for the protected stand was 1.0 in May and June; and for the grazed stand the range was 1.79 to 3.44 from December to May (Table IV 5). This higher ratio indicated a higher proportion of organic matter stored in underground phytomass than aboveground on grazed stand.

The value of net aboveground production of grazed stand was found much lower than that of protected stand (Table V 3), which revealed another important aspect of grazing. Therefore, under the same climatic conditions, the difference in the net aboveground production values of the two stands is supposed to be due to grazing influence of large herbivores.

Thus it can be concluded, that the community under grazing pressure suffer a loss in organic matter more than the amount removed by large herbivores, obviously due to the damaging effects of defoliation and trampling of the plant species (Misra, 1968).

CHAPTER VI

ENERGETICS

As Park (1946) stated that 'probably the most important ultimate objective of ecology is an understanding of community structure and function'.

The solar energy perceived by the green leaves of the plants, gets converted into chemical energy, which is stored in the organic matter and is a source of food for all the heterotrophs. The total amount of energy fixed is usually called as the 'Gross production' and the amount stored after respiration losses in the phytomass is 'Net production'.

According to Phillipson (1966) 'Ecological energetics is the study of energy transformation within an ecosystem'. In plant communities the estimation of caloric values, energy content and energy flow studies have been made in U.S.A. by Golley (1960, 61 and 65), Weigert and Evans (1964) in an old field community and by Williams (1966) on a California range.

In India, the caloric values and energy content of grassland communities have been estimated by Choudhary (1967), Singh (1969), Dwivedi (1970), Maurya (1970) and Singh (1972b) at Varanasi. Further studies have been made by Gupta (1971) at Gyanpur, Jain (1971) at Sagar, Mall (1972) and Misra (1973) at Ujjain, Billore (1973) at Ratlam, Naik (1973) at Ambikapur,

Das (1974) and Asthana (1974) at Gorakhpur, Trivedi (1976) and Gupta (1976) at Jhansi.

METHODS

The caloric values were determined from the samples collected at monthly intervals of the year 1977-78. The samples of each month were separated into standing live, standing dead, underground and litter components and subjected to drying in an oven at 80°C for 48 hours. After drying, the plant material was grinded in an electric grinder and the powders so obtained for each component was compressed into pellets (about one gram) to estimate its calorific value per gram dry weight of the plant material.

The caloric value for each sample was calculated from the increase in temperature after ignition in an oxygen bomb calorimeter at 12.5 lb pressure.

Calculation:

$$E = \frac{W1\ (t2-t1) + W2\ (t2-t1)}{W} \text{ calories per g dry wt.}$$

Where,

W1 = Water equivalent of bomb vessel (gm)

W2 = Weight of water in gram

W = Weight of pellet of plant material (gm)

E = Caloric values of plant material

t1 = Initial temperature (°C)

t2 = Final temperature (°C)

It is a standard practice to express all interspecific differences on a cal/g ash free dry weight basis. Therefore, the calorific values of each component on ash free dry weight basis were obtained by applying the estimate of ash percentage to the cal/g dry wt. value calculations.

ENERGY STUDIES

Monthly average of calorific values

Standing live component

It is evident from Table VI 1 that the maximum average energy accumulation of standing live component was 4575 calories/g dry wt. in November and minimum in May i.e. 3353 calories/g dry wt. Thus it was observed that storage of energy increased with the onset of rains due to growth of new tillers, with the maximum peak in November. After that the energy values showed a declining trend, except only a slight increase in January 4171 calories/g dry wt. due to the drying of annuals and perennials of the vegetation, reaching to a minimum value in May.

Standing dead component

The maximum average energy accumulation of standing dead component was 4356 calories/g dry wt. in November and minimum energy was obtained 3221 calories/g dry wt. in May. The trend of variation of this component was almost similar to that of standing live component but the values were lower.

Table IV 1: Monthly variation in caloric value (Cal/g dry wt.)

Months	St. Live	St. Dead	Under ground	Litter	Average
June	3618	3397	3795	3437	3562
July	4083	3846	3625	3012	3641
August	4166	3941	3645	2920	3668
September	4354	4011	3732	3389	3871
October	4474	4230	3828	3468	4000
November	4575	4356	4375	3508	4203
December	3958	3820	4215	3700	3923
January	4171	4100	4574	3409	4069
February	4073	4023	4280	3593	3992
March	3815	3680	4055	3351	3725
April	3453	3316	3927	3301	3499
May	3353	3221	3858	3034	3366
June	3640	3390	3840	3465	3584
Average	3979	3794	3980	3374	3777

Underground component

The monthly average calorific value of underground component was found more in winter season with two peaks, one in November (4375 calories/g dry wt) and another in January (4574 calories/g dry wt). The value of January was higher than the value of November. The trend of variation was not regular. From June onward, with the onset of monsoon, the energy values declined first and then increased till November. This decrease in the initial stage i.e. in July, might be due to loss of energy rich substances as a result of decomposition or by an upward flow of energy rich substances used in the growth of new tillers.

Litter component

Litter component revealed a lower calorific values, as compared to other components, with a maximum value of 3700 calories/g dry wt. in December and minimum in May i.e. 3034 calories/g dry wt. The trend of variation was almost similar to that of underground component, with an initial decrease of values in the rainy season followed by an increase in post-monsoon and winter months and again decreased in summer months.

Monthly average caloric values on ash free dry weight basis

The standing live component, standing dead, underground and litter component revealed the same trend of variation (Table VI 2) as obtained in monthly average caloric values on per gram dry weight basis, with maximum and minimum values in the same months.

Table VI 2: Monthly caloric value/gm ash Free Dry wt. of components (Cal/g)

Months	St. Live	St. Dead	Under ground	Litter	Average
June	4009	3749	4210	4053	4005
July	4568	4265	3978	3620	4107
August	4612	4341	3992	3464	4102
September	4677	4470	4252	4013	4353
October	4906	4782	4506	4434	4657
November	5310	5065	4821	4556	4938
December	4420	4233	4644	4766	4515
January	4746	4586	5005	4280	4654
February	4458	4523	4745	4683	4602
March	4180	4189	4531	4215	4279
April	3792	3665	4463	4095	4004
May	3613	3552	4320	3840	3831
June	4060	3730	4280	4004	4018
Average	4411	4250	4442	4155	4313

Variation in average caloric values of different months

The estimation of average caloric values of different components on monthly intervals revealed a definite trend. With the onset of monsoon the average caloric value per month increased gradually from June onward with a maximum of 4203 calories/g dry wt. in November, after that it declined till May with a minimum value of 3366 calories/g dry wt. except a slight increase in January 4069 calories/g dry wt.

The same trend was observed in ash free dry weight basis.

Energy Storage (K cal/m^2)

Energy storage or structure in the plant materials have been calculated by multiplying the phytomass values in g/m^2 with their respective energy values (calories/g dry wt.). As the two values showed a considerable variation at monthly intervals, the energy storage of different components have been calculated separately (Table VI 3) and then aboveground and underground standing crop of energy have been calculated from these storage values.

The trend was found similar to that of standing crop of organic matter. Maximum energy storage in the aboveground phytomass was recorded 7599.1 K cal/m^2 in October. This maximum value was due to maximum standing live phytomass share in the same month. The maximum standing crop of energy in the underground phytomass was recorded 3455.4 K cal/m^2 in winter season i.e. November and next maximum 3430.5 K.cal/m^2 in January (Table VI 3).

Table VI 3: Monthly variation in energy storage (K cal/m^2)

Months	St. Live	St. Dead	Litter	Total Aboveground	Underground	Total
June	289.4	686.1	628.9	1604.4	944.9	2549.3
July	1188.1	423.0	195.7	1806.8	1166.9	2973.7
August	3240.8	315.2	75.9	3631.9	1468.1	5100.0
September	4171.1	822.2	281.2	5274.5	1963.0	7237.5
October	5525.3	1501.6	572.2	7599.1	2469.0	10068.1
November	4327.9	2400.1	687.5	7415.5	3455.4	10870.9
December	1666.3	2398.9	1091.9	5157.1	2887.2	8044.3
January	2335.7	2250.9	767.0	5353.6	3430.5	8784.1
February	1889.8	2413.8	549.7	4853.3	2453.4	7306.3
March	1251.3	1383.6	831.0	3465.9	1861.2	5327.1
April	694.0	716.2	1122.3	2532.5	1276.2	3808.7
May	285.0	724.7	809.3	1819.0	1196.2	3015.2
June	509.6	610.2	693.0	1812.8	1278.7	3091.5
Average	2160.2	1203.6	638.9	4025.1	1988.5	6244.4

On an annual basis the average energy storage of the aboveground standing crop was recorded as 4025.1 K cal/m^2 and for the underground 1988.5 K cal/m^2.

Relationship between aboveground and underground standing crop of energy

A significant positive correlation was observed in the aboveground and underground standing crop of energy ($r = 0.86$, $P < .001$) which indicate that energy increases simultaneously both in aboveground and underground parts of producers. Such significant positive correlation (Fig. 14) between these parameters has also been reported by Singh (1972b) and others from different grassland communities.

Net Energy Fixation

Energy fixed by a plant community derives the functioning of the ecosystem and the efficiency of energy fixation is a reflection of the ecosystem's functional potential. The net amount of energy fixed is the amount left after respiration losses in a plant community. Net energy fixation has been calculated by the summation of positive increases of energy storage in standing live on successive months, plus concomittent increases in energy storage of standing dead and litter component. Seasonal as well as annual calculations have been made.

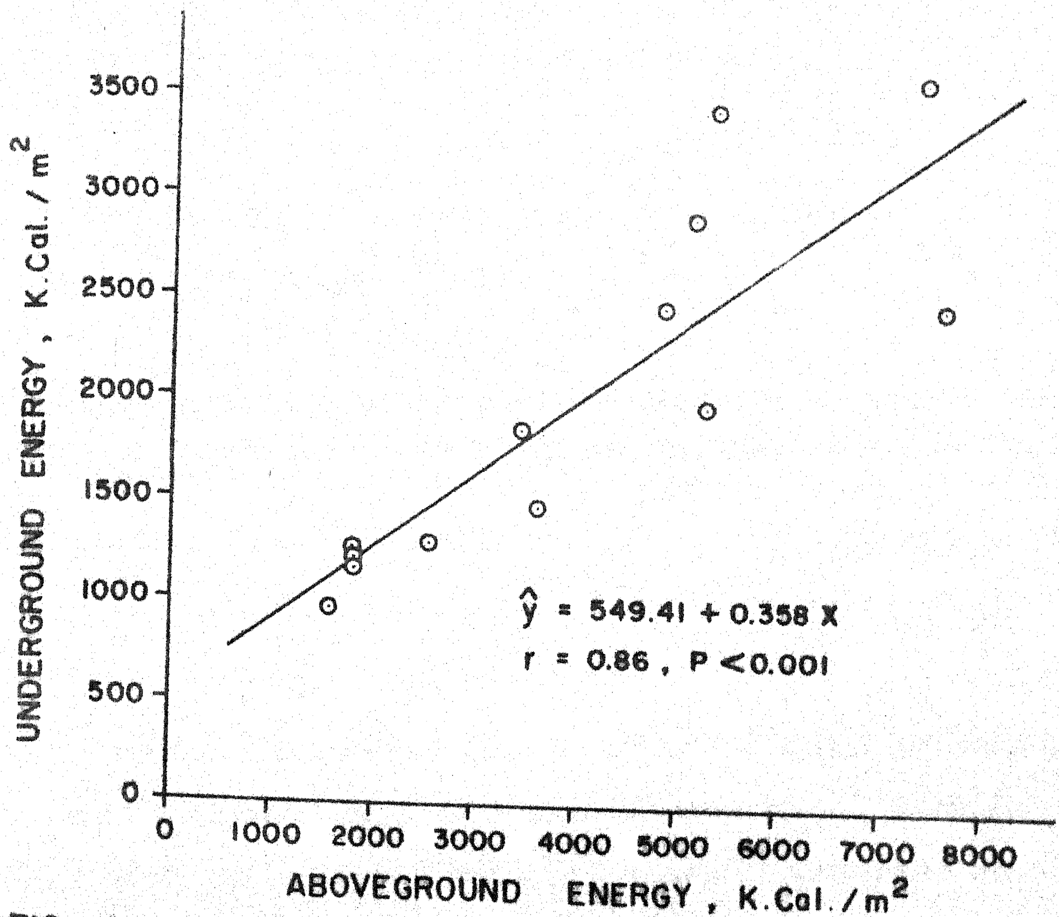


FIG. 14 – RELATIONSHIP BETWEEN ABOVEGROUND AND UNDERGROUND ENERGY.

Table VI 4: Seasonal/Annual Net Energy Fixation (K cal/m^2)

	Rainy	Winter	Summer	Annual
Aboveground	6918.6	669.4	224.6	7812.6
Underground	1524.1	1529.7	82.5	3136.3
Total community	8442.7	2199.1	307.1	10948.9

On perusal of the above table it is clear that the maximum energy fixation was(8442.7 K cal/m^2) in rainy season specially in October (postmonsoon period), followed by winter (2199.1 K cal/m^2) and summer(307.1 K cal/m^2).

In rainy season, out of the total energy value of aboveground(6918.6 K cal/m^2), standing live contribution was 5235.9 K cal/m^2 (75.6%), standing dead 1186.4 K cal/m^2 (17.2%) and of litter component was 496.3 K cal/m^2 (7.2%).

The net energy fixation value of underground component revealed maximum energy in winter season(1529.7 K cal/m^2), followed by rainy season(1524.1 K cal/m^2) and summer season (82.5 K cal/m^2).

Annual total net energy fixed by the vegetation was obtained 10948.9 K cal/m^2. The aboveground share was 71.4% and underground share was 28.6%.

Energy Transfer through litter fall

The green plant phytomass converts the solar energy into chemical energy, which is fixed in the plant parts. Out

of the net amount of energy fixed, a sizeable amount is lost to the soil, through the annual litter fall and its decomposition by the activity of microorganisms. The energy stored in the litter component is finally released to the soil.

This energy transfer has been estimated by multiplying the litter phytomass (g/m^2) with their respective energy concentration (cal/g dry wt.).

As evident in Table VI 3 monthly transfer of energy through litter fall showed a definite trend. It started in the month of September and continued in winter and summer months, reaching a peak value in April. The net transfer of energy was maximum in December(404.4 K cal/m^2) and next higher was in April(291.3 K cal/m^2).

Energy Accumulation in Litter

In rainy season, the energy stored in the litter was released to the soil by the decomposition due to the activity of microorganisms. But after August the energy started accumulating due to continuous litter fall and slow rate of decomposition in winter and summer months.

The accumulation of energy was more (1091.9 K cal/m^2) in winter (December) and highest (1122.3 K cal/m^2) in summer (April), due to the continuous addition of litter and slow rate of decomposition. The lowest accumulation of energy was (75.9 K cal/m^2) in August (rainy season).

Energy Release through litter

The method proposed by Singh and Yadav (1974) was employed here to estimate the release of energy through litter.

(Initial Energy + Energy Maximum) - Energy of final litter

In the present investigation, as the energy values of different sampling periods fluctuate very much, the net production value for the period was considered and seasonal and annual release of energy was calculated.

It was observed that maximum energy (553.0 K cal/m^2) was released in rainy season through litter fall, followed by winter season (542.2 K cal/m^2) and minimum energy release was (429.3 K cal/m^2) in summer.

On an annual basis total amount of energy released through litter was 1524.5 K cal/m^2.

Energy turnover

The turnover of energy is associated with process on and in the soil and therefore, the amount of energy accumulating on the soil surface is essential. The amount of energy accumulated on the soil 'X' at a given time 't' is described with the relation,

$$dx/dt = L - K' x$$

Where L is the amount of energy transferred to the ground through litter fall and K' is the decomposition rate.

The relation can be written as :

$$K' = \frac{L}{x}$$

By means of K' the dynamics of litter energy can be characterised. Value of K' was derived from the average energy storage (Table VI 3) and energy accumulation through litter fall.

Turnover time is the reciprocal of turnover rate and is expressed as 1/K. Thereofere, turnover time is the time required to decompose the residual litter.

Turnover of Energy

Turnover rate K'		Turnover time 1/K	
10^{-2}/day	Per Year	Days	Year
.68	2.48	147	.40

Thus the rate of energy release to the soil is 2.48/Yr or .68 10^{-2}/day and the time required for total decomposition of the residual litter to release energy will be .40/Yr or 147 days.

Efficiency of energy capture

Conserving efficiency of primary producers is the ratio of output (calories captured by the vegetation) to input (solar radiation) in an unit area over a definite length of period.

The efficiency of energy capture has been calculated on the basis of the following formula:-

$$= \frac{\text{Energy capture/m}^2\text{/t}}{\text{1/2 solar radiation}} \times 100$$

t = period of solar radiation and energy capture.

Energy captured by the green plant materials has been calculated by multiplying the phytomass values in g/m^2 with the respective energy concentrations (calories/g dry wt.) and net energy captured has been calculated by the summation of positive increases of energy storage in standing live on successive months, plus concomittent increases in energy storage in standing dead and litter components on seasonal basis as well as annual (Table VI 3).

It is generally agreed that the total solar radiation in the 0.4 - 0.7u waveband is available to green plants. Therefore, in the present calculation only half of the solar radiation has been considered and referred to as usable solar radiation (U.S.R.). This amount is roughly equal to the amount available to plants for photosynthesis (Terrien et al., 1957; Daubenmire, 1959). The previous authors (Singh and Misra, 1969; Sims and Singh, 1971; Singh, 1972b; Singh and Yadav, 1974) have used the same percentage of solar radiation for calculating effieiency.

The values obtained for efficiency of energy capture are presented in the Table VI 5. It is evident from the table that in aboveground part efficiency of energy capture was maximum (2.91%) in rainy season and minimum (0.07%) in summer season. On the other hand in underground parts the maximum efficiency of energy capture was in winter season (0.72%) and minimum in summer season (0.03%). Thus it is

clear that more of the energy captured was accumulated in the aboveground part during wet period and transferred to underground part during dry period.

Table VI 5 : Efficiency of Energy capture

Energy use			Efficiency %
Aboveground			
		Rainy	2.91
		Winter	0.31
		Summer	0.07
	Total	Annual	1.04
Underground			
		Rainy	0.64
		Winter	0.72
		Summer	0.03
	Total	Annual	0.42
Total community			
		Rainy	3.56
		Winter	1.04
		Summer	0.10
	Total	Annual	1.46

Considering the community as a whole, the efficiency of energy capture was maximum (3.56%) during rainy season and minimum (0.10%) in summer, the winter season value

(1.04%) occupied an intermediate position. Therefore, it is quite apparent that most of the net annual energy accumulation has occurred during July to October, which, therefore, constitutes the grand period of growth for the community.

Efficiency of energy capture, on an annual basis, revealed greater percentage (1.04%) in aboveground part than in underground (0.42%) and for the total community the value comes to 1.46%. This high value of efficiency indicates that the present community is more efficient or potential in capturing solar energy, resulting into high productivity.

DISCUSSION

The calorific value of plant material depends upon the quality and quantity of reserve food in it. Further the energy content of a plant or its components are governed by its fat content or nutritive status and also its genetic constitution and stage of the life history. Among the compounds which store energy in plants are carbohydrates, proteins and lipids. Fats store maximum energy. These factors are highly influenced by environmental conditions and thus affecting the calorific value of plant material.

According to Long (1934) seasonal variation in calorific value depends on the variation in light intensity, length of the day, amount of nutrient and type of soil in which plants grow. Thus depending on the seasonal variation the energy values exhibited significant monthly variation.

In the winter season caloric values are usually high on per gram dry weight basis or ash free dry weight basis, this is because low temperature favour synthesis of fat. Choudhary (1967) has also reported high caloric values during winter season.

The rainy season shows an increasing trend in energy due to vegetative growth, while in summer drier months a decreasing trend was observed, it may be due to increasing rate of respiration under high temperature of summer, resulting into decrease of reserve food.

Dwivedi (1970) has explained the reduction in caloric values during summer on the basis of reduction in fat content due to deep root penetration during summer months and low phosphorus status. He has also explained seasonal variation of caloric values on the basis of variation in energy rich compounds like carbohydrates, proteins and fats with the advancement of age. The above facts were found true in the present investigation also.

Accumulation of energy in plant parts significantly depends on the climatic conditions and the response of the plants. In the present investigation maximum energy was accumulated in the above ground standing component during rainy season (October) due to maximum growth of organic matter (Table VI 3).

There is a gradual fall in the average energy values from standing live to standing dead and to litter components, due to weathering and decay of organic matter. This is in conformity with the findings of Ovington and Heitkamp (1960), Golley (1965), Choudhary (1967), Jain (1971), Das (1974) and Trivedi (1976).

The underground parts revealed maximum energy accumulation in winter season (November and January) after that there is a declining trend in the summer months. The high caloric values in winter, of underground parts indicated more accumulation of organic matter in roots, which is required for survival of aboveground parts in lean period. A high positive correlation was observed between aboveground and underground standing crop of energy with correlation coefficient $r = 0.86$, $P < .001$. Similar relationship was observed by Singh (1972b).

The energy stored in the plant material was transferred to the floor through litter fall, as a result of death of annuals and gradual drying of perennials. Litter revealed lower caloric values. Lower energy values in litter may be ascribed to its ash content, which is mainly composed of noncombustible elements like silica, calcium, magnesium and some contaminants like soil particles (Kandya, 1974). The energy thus transferred through litter fall was released to the soil by the decay and decomposition of litter due to the activity of microbes inhabiting the soil. In the begining,

with the onset of monsoon, the release of energy was more due to rapid rate of decomposition of the residual litter of the previous year but later on in postmonsoon period the rate gradually declined. Out of the total amount of energy released through litter decomposition, the maximum percentage (36.3) was in rainy season followed by winter (35.5) and summer (28.2). The rurnover rate of energy release to the soil is 2.48/yr or .68 10^{-2}/day and the time required for total decomposition of the residual litter to release energy is 0.40/yr or 147 days.

The average energy values of different communities on dry weight basis are represented in Table VI 6. It is evident from the table that overall average caloric values vary in different communities. This has been explained by McNair (1945) that with the increasing altitude, latitude and decrease in temperature, there was a corresponding increase in fat content, resulting into high caloric values. The average caloric value obtained in the present investigation is well within the range of other tropical grassland communities. The value very similar to Varanasi, Gorakhpur and Sagar grasslands.

The efficiency with which the energy is trapped, accumulated and dissipated at different trophic levels in the ecosystem are of significance. The high value (1.46%) of efficiency of energy capture was found in the present investigation, indicating the grassland communities of this region have a high potential for capturing solar radiation.

Table VI 6: Average energy values of some ecological communities

Community	Place	Value	Authority	Year
Tropical rain forest	North America	3897	Golley	1961
Old field broom sedge	South Carolina	3999	Golley	1965
<u>Dichanthium</u>	Varanasi	3887	Choudhary	1967
<u>Heteropogon</u>	Sagar	3862	Jain	1971
<u>Heteropogon</u>	Varanasi	4887	Singh	1972b
<u>Heteropogon</u>	Varanasi	4040	"	"
<u>Vetiveria</u>	Varanasi	3865	"	"
<u>Sehima</u>	Ratlam	3403	Billore	1973
<u>Dichanthium</u>	Ujjain	3330	Misra	1973
Wheat (P.S.)	Gorakhpur	4139	Das	1974
<u>Cynodon</u>	Gorakhpur	3797	Asthana	1974
<u>Sehima</u>	Jhansi	3487	Trivedi	1976
<u>Dichanthium</u>	Varanasi	3884 3900	Pandey	1977
<u>Dichanthium</u>	Orai	3777	Present study	1980

The seasonal fluctuation trend of energy conserving efficiency for total vegetation is similar to that of net dry matter production, sinceenergy conserving efficiency is calculated on the basis of the net dry matter production, caloric value and solar energy available on the land surface.

Singh and Misra (1968), Singh and Yadav (1974) have reported greater efficiency of energy capture in aboveground part than underground part. The same is observed here which indicates that under warm and wet condition more energy is fixed in aboveground part. Greater efficiency during wet period is obviously due to higher green phytomass and more moisture.

Efficiency of energy capture values for different tropical and temperate grasslands are presented in Table VI 7. A perusal of this table clearly indicates that the efficiency of energy capture in the present investigation is much greater than in the temperate grasslands (except Meadow Steppe, West Siberia) and some tropical grasslands.

Although, the percentage efficiency of the present grassland is found lower to the values of Varanasi (Singh and Misra, 1968; Singh, 1972b) and Kurukshetra grassland (Singh and Yadav, 1974), yet it is more efficient as compared to the grasslands of Gyanpur (Gupta, 1971), Ujjain (Misra, 1973), Gorakhpur (Asthana, 1974) and Jhansi (Trivedi, 1976). The higher efficiency values have also been reported by Pandeya (1974) and Saxena et al. (1974).

Table VI 7: Energy conserving efficiency of different communities

Community	Place	Efficiency (%)	Author	Year
Dense Festuca thurberi	Colorado	1.2	Turner and Dortignar	1954
Poa Compresa	Michigan	1.1	Golley	1960
Short grass steppe	Colorado	1.3	Klipple and Costello	1960
Meadow steppe	West Siberia	3.4	Rodin and Bazilevich	1965
Tall grass prairie	Missouri	1.2	Kucera *et al.*	1967
Tall grass prairie	Colorado	1.2	Moir	1969
Short grass steppe	Colorado	0.16 - 0.97	Sims and Singh	1971
Tropical grassland	Varanasi	1.67	Singh and Misra	1968
Dichanthium grassland	Gyanpur	0.98	Gupta	1971
Heteropogon	Varanasi	3.19	Singh	1972b
Heteropogon	Ujjain	0.38	Misra	1973
Cynodon (C/P)	Gorakhpur	0.84	Asthana	1974
Tropical grassland	Kurukshetra	1.66	Singh and Yadav	1974
Dichanthium	Varanasi	0.28	Choudhary	1974
Sehima	Jhansi	1.17	Trivedi	1976
Dichanthium	Orai	1.46	Present study	1980

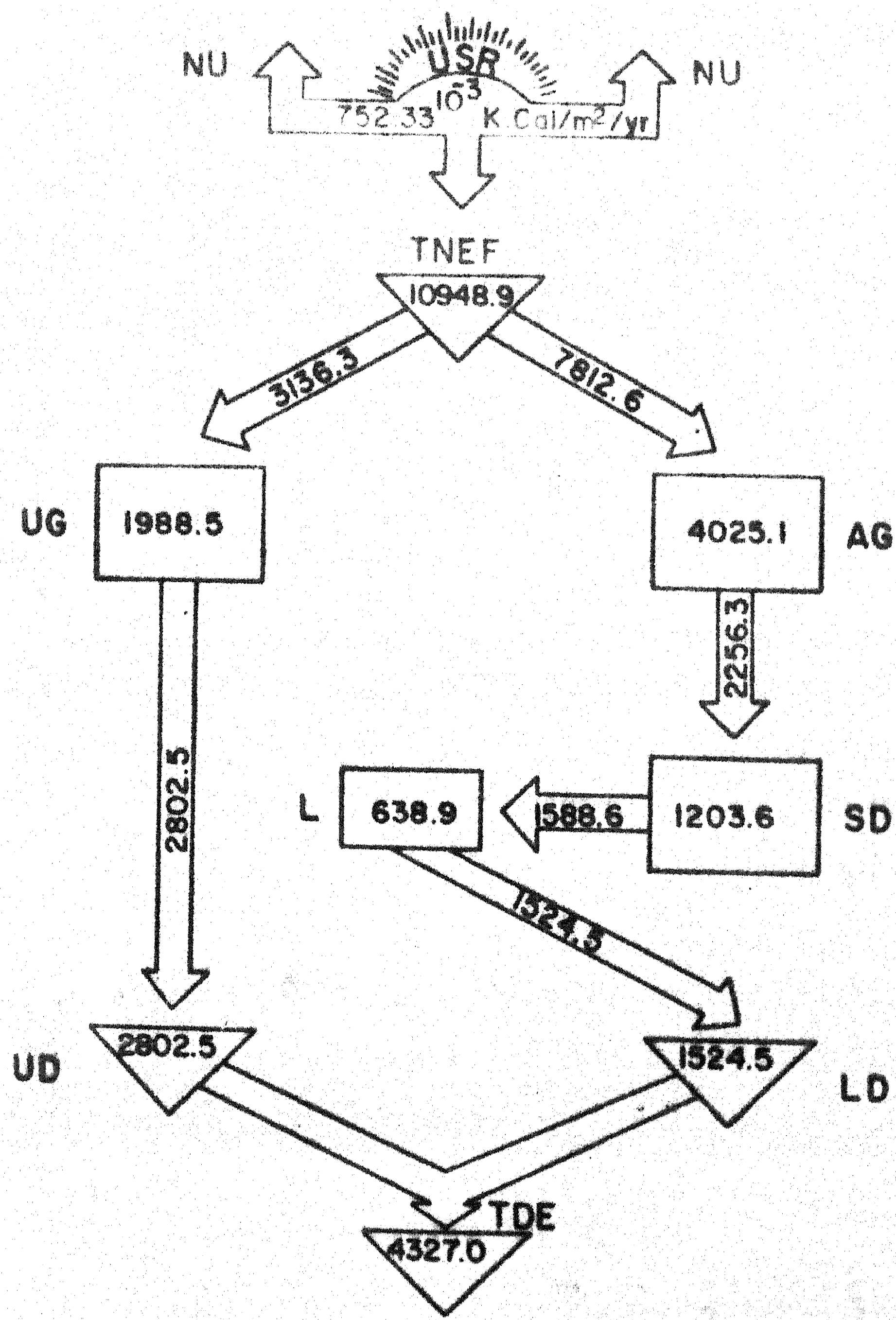
The year long growing season, abundant precipitation, high light intensity and preponderance of C_4 plants in tropical grasslands seems to favour greater efficiency of energy capture.

Energy balance

Energy balance of the ecosystem could be prepared by calculating various rates of input to the system and output from the system. Energy transfer rates between components and standing state of energy within the components have been shown in energy flow model. Each component has been shown in separate compartments with its own output and input. Values on arrows and within the triangles represents flow rates K cal/m^2/year and values inside the rectangular compartments denote the standing state of energy K cal/m^2.

Annual net energy fixed by the community was 10948.9 K cal/m^2/yr, as represented in energy flow model. Out of this total energy fixed by the vegetation, 7812.6 K cal/m^2/yr was transferred to aboveground parts (71.3%) and 3136.3 K cal/m^2/yr to underground parts (28.6%).

Out of the total amount of energy retained in the aboveground, 2256.3 K cal/m^2/yr was transferred to standing dead component (28.9%). From standing dead component 1588.6 K cal/m^2/yr (70.4%) was transferred to litter component and the rest amount of energy was carried over to next year. Thus out of total energy 7812.6 K cal/m^2/yr retained in the



ENERGY FLOW MODEL

aboveground parts, only 20.3% was finally transferred to litter compartment. This energy of the litter component was finally made available to soil for decomposition process of microbes and the same was calculated as per method of Singh and Yadav (1974). Thus out of 1588.6 K cal/m^2/yr energy of the litter component 1524.5 K cal/m^2/yr was made available to the soil.

The underground parts through disappearance released 28025 K cal/m^2/yr (89.3%) of the total energy fixed. The same was calculated by summing the negative changes in the energy storage of the underground parts. The rest amount was retained in the root system.

Thus total amount of energy transferred to the soil as a result of release of energy through litter decomposition and through root disappearance was found as 4327.0 K cal/m^2/yr. So, within a year 40% of the total energy fixed by the community disappeared from the system via litter and under ground disappearance and rest was either lost through various ways or sustained in the system.

System Transfer Function for energy

The transfer of energy from one compartment to another compartment is shown in the Table VI 8.

The transfer from T.N.E.P. to A.N.P. is maximum 81% in rainy season and minimum 30% in winter season. While the transfer from T.N.E.P. to U.N.P. is maximum 69% in winter

season and minimum 18% in rainy season. Considering the annual transfer of energy from T.N.E.F. to A.N.P., it is 71% and from T.N.E.F. to U.N.P. is 29%.

Table VI 8 : S.T.F. (Energy)

Components	Rainy season	Winter season	Summer season	Annual
T.N.E.F. to A.N.P.	.81	.30	.73	.71
T.N.E.F. to U.N.P.	.18	.69	.26	.29
A.N.P. to S.D.	.17	1.58	.03	.29
S.D. to L.	.42	.49	67.36	.70
A.N.P. to L.	.07	.77	2.54	.20
L. to L.D.	1.11	1.04	.74	.95
U.N.P. to U.D.	-	1.01	15.23	.89
T.N.E.F. to T.D.	.07	.95	5.49	.40

The transfer of energy from A.N.P. to standing dead (S.D.) is maximum 158% in winter, while annual value comes to 29%. Thus annual disappearance is lesser to annual accumulation.

From S.D. to L. transfer of energy is maximum 6736% in summer and minimum 42% in rainy season. This is obviously due to the fact that S.D. of preceeding period is also transferred to L during summer. The annual transfer is 70%. Reverse to

this, transfer of energy from L. to L.D. is found maximum 111% in rainy season and minimum 74% in summer. High moisture and warm temperature results in such a high rate of disappearance in rainy season. Annual disappearance comes to 95%.

Thus period of disappearance does not coincide with the period of accumulation and high rate of accumulation is found in summer, while high rate of disappearance is in rainy season.

Transfer of energy from U.N.P. to U.D. is found maximum 1523% in summer. This high rate in summer is due to high phytomass value and negative differences in the values. Annual transfer of energy from U.N.P. to U.D. is 89%.

The total disappearance of energy from T.N.E.F. is 40% and the rest amount is either carried over to next year or lost by some other means.

CHAPTER VII

GENERAL DISCUSSION AND CONCLUSION

In the foregoing pages at the end of each chapter a specific discussion has already been made regarding the structural and various functional aspects of the ecosystem studied. Based on the data of the present study and the studies of other workers, one can attempt to give an idea of the whole picture. In this chapter a synthesis of such information has been attempted and an effort has been made to give an idea of structural and functional aspects of the grasslands studied. Odum (1962) emphasized the study of both structure and function in understanding and controlling nature.

The region where the two grasslands studied are situated experiences a long, hot and dry summer season, low precipitation and small winter season. Ombrothermic conditions of the area revealed 8 dry months and 4 wet months during a year (Fig. 2). On the basis of moisture index value (-1.70), as derived according to Thornthwaite and Mather (1955) the area can be classified as dry subhumid (C_1) with the ecoclimatic formula as C_1 A_2' a_2' s.

The species composition varied on both the stands showing prominent seasonal changes (Table III 1). The maximum species diversity was recorded on protected stand than on grazed one. It appeared that protection against

grazing by large herbivores had given fair chances for the establishment or growth of those species which were unable to do so under the grazing pressure on grazed stand. Trivedi (1976) has explained such a variability in species composition due to microedaphic and topographic variations. The importance of soil moisture in species diversity has also been advocated by Daubenmire (1959) and Trivedi (1976). The soil moisture and protection against grazing seems to be the chief factors responsible for species diversity in these grasslands. Golley and Gentry (1965), Gupta et al. (1972) and Naik (1973) have also noted higher number of species on protected communities.

Every year with the onset of monsoon a flush of species appear, the annuals complete their span of life usually upto winter and then disappear leaving perennials to survive in dry and unfavourable period. The periodic climate is manifested in phenological diversity (Pandeya et al.,1977). A great proportion of therophytes in the biological spectrum of these grassland stands might indicate a therophytic phytoclimate of the area, but the abundance of therophytes is also attributed to greater biotic disturbances. The higher number of therophytes in Indian grasslands have been reported by Bharucha and Dave (1944) and Pandeya (1953).

It is interesting to note that the percentage frequency of various species grouped under Raunkiaer's frequency classes

was quite dissimilar than that of the normal frequency diagram. The percentage of species in the five frequency classes showed that $A > B > C > D \geqq E$ for both the stands indicating a greater floristic heterogenity of vegetation.

D. annulatum showed its maximum I.V.I. in all the seasons on protected stand (Table III 5a). Though its prominance was observed including *D. bipinnata* on the grazed stand for the whole year, however, *Cassia tora* resulted in maximum I.V.I. during rainy and *Rungia repens* in winter seasons (Table III 5b). This is probably due to the wide distribution and higher phytomass contribution of these species. Therefore, *D. annulatum* can be considered as a dominant species of protected stand, whereas both i.e. *D. annulatum* and *D. bipinnata* were found dominant species on grazed stand. Greater I.V.I. of dominant and other perennial species during summer months, on the stands studied, may be ascribed to the absence of other associates in the community (Misra, 1973; Asthana, 1974 and Trivedi, 1976).

In grassland communities, changes in the phytomass values at short intervals are attributed to the marked variations in the Ombrothermic and soil conditions to which the phenology of herbaceous species is strongly adapted and adjusted (Singh, 1978). There are great variations in the standing crop phytomass in different months according to seasonal conditions. The standing crop of aboveground plant

material, in the present study, showed maximum value in October on protected and in September on grazed stands (Table IV 2a,b), probably due to the lush growth of various species with the onset of monsoon. On the protected stand, the aboveground phytomass decreased after October due to the death and shattering of annual species as well as seasonal tillers of perennial grasses following maturity. While on grazed stand, this decline was observed after September, mainly due to grazing pressure. In January there was a slight increase in aboveground phytomass reflecting new growth; which is a common feature in the Indian climatic conditions (Misra, 1959). Pandeya _et al_. (1977) also emphasized that the changes in the aboveground phytomass varied from locality to locality, depending upon the ecoclimate.

It was recorded that a major portion of the aboveground phytomass was contributed by dominant grass _D. annulatum_ on protected stand and by _D. annulatum_, _D. bipinnata_ and _Cassia tora_ on grazed stand. According to Jankowska (1968) the protection allowed better growth of grasses and thus contribution made by grasses increased with an increase in protection.

If the maximum value of aboveground phytomass is compared with the reports of other tropical grasslands (Table IV 9). The value of protected stand is higher to that of Sagar (Jain, 1971), Jhansi (Gupta, 1976), but lower than that of

Kurukshetra (Singh and Yadav, 1974); and the maximum value of aboveground phytomass of grazed stand is lower to other reports.

The aboveground phytomass is positively related to the total density i.e. tiller/m^2 ($r = 0.87$, N.S.) and $r = 0.95$, $P < 0.05$) for protected and grazed stands respectively (Fig.8a). Similarly, it was also found that basal cover of the species is directly related with the phytomass of the community ($r = 0.89$, NS and $r = 0.97$, $P < 0.05$) for both the stands respectively (Fig. 8b). Both these statistical relations reveal that with an increase in the density and basal cover of the species the phytomass increased, which is in conformity with the observations of Gupta (1978).

Studies on vertical distribution of phytomass provide an insight regarding the understanding of stratification in a community. Data of aboveground phytomass obtained in the present study resulted in an upright pyramid (Fig. 7), which showed combined effect of species resulting in some sort of uniformity in distribution and phytomass. Singh and Yadav (1974) observed similar stratification in the aboveground phytomass.

In the present investigation underground phytomass increased apparently due to the accumulation of organic matter during rainy season on both the stands, as has also been reported by Billore (1978). A decrease in underground phytomass was recorded during winter and summer seasons,

which may be explained due to cessation of growth and death of the root system under hot and dry conditions and/or due to disappearance of root system during pre-monsoon period, as new tillers appear from March to June at the expense of the root phytomass. Comparatively greater phytomass value on protected stand than that of grazed clearly indicate the effect of protection against grazing.

On comparing the maximum underground phytomass with other reports (Table IV 9), the value is quite low to that of Jain (1971), Naik and Mishra (1974), Singh and Yadav (1974) and Agnihotri (1979) for protected stand. Varshney (1972) and Gupta (1976) have reported still lower values. Similarly, the value for grazed stand is also lower to that of Gupta (1976) and Agnihotri (1979).

U.G./A.G. phytomass ratio remained always lower than one except in the month of May on protected stand, because aboveground phytomass could not with-stand the hot summer dry month. While it was more than one throughout the winter and summer seasons on grazed stand, probably due to grazing pressure. These results are in accordance with those of Naik (1973), Asthana (1974) and Trivedi (1976). According to Pandeya et al. (1977) the ratio of U.G./A.G. phytomass varied and increased under semiarid conditions. Further he stated that accumulation of aboveground and underground organic matter depended on ecoclimate, totality of soil

character and phenology. The annual average ratio of U.G./A.G. in the present investigation (0.65 and 1.62 for protected and grazed stands) could be compared with the ratio of other reports (Table IV 10). The ratio of protected stand is almost equal to that of Singh (1967), Jain (1971) but lower to that of Choudhary (1972), Dakwale (1975), Trivedi (1976) and Agnihotri (1979). Similarly, the annual average ratio of U.G./A.G. of grazed stand is higher to that of Gupta (1976) but lower to Agnihotri (1979).

Thus it is not true that there is no growth in total phytomass during the dry months but it is negligible as compared to respiratory loss and drying; and withering of old growth because of extremem hot and dry conditions.

Statistically significant positive relationship ($r = 0.99$, $P < 0.001$) between leaf Area Index (I.A.I.) and photosynthetic green phytomass is noteworthy as leaf area is the key factor for organic matter accumulation (Fig. 10). High L.A.I. value (6.26 m^2/m^2) during monsoon period supports the findings of Billore (1973).

The maximum chlorophyll content (1.26 g/m^2) of grasses in the present investigation (Table IV 8) is slightly higher than the values of many temperate communities (0.3 to 1.0 g/m^2) (Bray ,1960) and also to that of Billore and Mall (1976).

The chlorophyll <u>b</u> concentration was found significantly higher than chlorophyll <u>a</u> throughout the study

period. The lower concentration of chlorophyll a may be due to the possible conversion of chlorophyll a into chlorophyll b (Rebeiz and Castelfraco, 1973). It may also be due to the fact that small fraction of chlorophyll a gets converted to phaeophytin (Gorham, 1959; Gorham and Sanger, 1967). Higher proportion of chlorophyll a, observed in the present investigation, signifies its active role in photosynthesis, which is in conformity with the findings of Nandpuri et al. (1973), Radha Rani (1976) and Misra (1980).

A highly positive significant correlation was observed between chlorophyll concentration and green phytomass (Fig.11). This is in conformity with the observation of Kumar (1971), Billore and Mall (1976) and Joshi (1978), which indicate that with the increase in chlorophyll concentration green phytomass also increases. Gill (1975) has observed that increase in chlorophyll concentration is positively related to net production. Bliss (1966) and Tieszen and Bonde (1967) also reported a very high correlation between chlorophyll and dry weight in Arctic and Alpine ecosystems.

In grasslands the annual primary productivity is largely influenced by the amount and distribution of rainfall. Higher rainfall in tropics increases the productivity (Whyte, 1975). The aboveground net productivity (A.N.P.) in grasslands studied was recorded more than that reported by Golley and Gentry (1965) for temperate grasslands. The higher value of A.N.P. on protected stand than that of grazed was obviously due to

heavy grazing by large herbivores in the latter. Thus protection seems to be a responsible factor for the increasement in production on the former stand. The values of A.N.P. (Table V 5) of the present study are very much comparable to that of a Dichanthium annulatum community studied by Jain (1971) at Sagar and a grassland dominated by Iseilema at Ujjain (Billore, 1978).

The higher value of underground net production (U.N.P.) on protected stand than of grazed may be attributed to the persistant removal of herbage aboveground on grazed stand. Trivedi (1976) and Agnihotri (1979) have also reported higher values of U.N.P. on protected sites than that of grazed. Singh and Yadav (1974) have explained higher U.N.P. in arid grassland due to xeric conditions, which faces deep root penetration.

Total net production (T.N.P.) in the present investigation, if compared with other grasslands (Table V 5) showed a higher net production than other Dichanthium dominated grasslands of Varanasi (Choudhary, 1972) and Ujjain (Misra, 1973; Billore, 1978), but the value is somewhat comparable to that of Sagar grassland (Jain, 1971). However, arid zone grasslands of Rajkot (Pandeya et al., 1977) and Kurukshetra (Singh and Yadav, 1974) exhibited quite high T.N.P. value. On the other hand, T.N.P. value of grazed stand is lower to

other grasslands because of herbage removal due to heavy grazing. The present community, under heavy grazing, showed a net loss of 67.8%, which is higher to other reports of tropical grasslands.

Thus the present investigation revealed that this grassland (protected) is more productive (23 ton/ha/yr) than other tropical grasslands, but the value is quite similar to that of Sagar (Jain, 1971), Varanasi (Ambashta *et al.*, 1972). It is about 4-5 times more than the average temperate rate of 5 ton/ha/yr (Whittaker, 1970). This difference may be due to the difference in the mechanism of carbon fixation in the tropical and temperate plants, because many tropical grasses and forbs fix carbon by C_4 pathway and not through the C_3 pathway, which is more common in temperate plants (Singh, 1978).

The relationship amongst species diversity, dominance stability and net production revealed (Fig. 12) that net production is inversely related to dominance index and directly related to diversity index. Therefore, the present findings support the observations of Patten (1963), Singh and Misra (1969) and Singh and Ambashta (1975), that 'Species diversity increases productivity efficiency of the system, while dominance makes the system stable, though less efficient for production'.

Out of the annual litter disappearance, maximum rate was recorded in rainy season on protected stand. This high rate of disappearance in rainy season is due to high moisture content and warm temperature, which favourably increases the growth of microbes and their activities. In contrast to this on grazed stand, the litter disappearance was recorded maximum in winter season. This may be explained that though the microbial activity is pronounced in rainy season, litter disappearance is limited by the amount of substrate available. Turnover rates revealed a fast replacement of litter on grazed stand than protected stand. Billore (1978) also reported the same results for Ujjain grasslands.

Organic matter dynamics revealed that annual production and disappearance of organic matter of protected stand is quite comparable to the reports of Billore (1978) for Ujjain but lower to that of Singh and Yadav (1974) for Kurukshetra grassland (Table V 12). The values of the grazed grassland of the present investigation could also be compared with the grazed grassland of Ujjain (Billore, 1978). Thus it can be concluded that rate of production and disappearance depends on the climatic conditions of the area and other local conditions.

A systematic analysis of the grasslands revealed that the value from T.N.P. to A.N.P. ranged from 39% to 69% in

Indian grasslands. In general this transfer function was more than T.N.P. to U.N.P. (Misra, 1973; Billore, 1973; Singh and Yadav, 1974; Gupta, 1976; Trivedi, 1976; Billore, 1978 and Agnihotri, 1979), except few grasslands where T.N.P. to A.N.P. was less than T.N.P. to U.N.P. The same trend is found in the present investigation i.e. T.N.P. to A.N.P. 74% and 58% and T.N.P. to U.N.P. 26% and 41% on the two stands respectively (Table V 13). It was observed that amount of loss of litter was more on grazed stand than protected stand. The values are nearer to the reports of Singh and Yadav (1974) and Agnihotri (1979).

Total values of loss of organic matter on protected (41%) and grazed (57%) stands are nearer to Ratlam (58%) Kurukshetra (59%) and Sagar (54%) grasslands (Table V 12). Billore (1978) reported greater loss at ungrazed site. Thus it can be said that the variations in different components of S.T.F. may be due to the differences in climatic, edaphic and floristic characters.

Insect causes a considerable problem in the tropics with the grassland; these insect populations are particularly conducive to instability (Van Dyne *et al.*, 1978). According to Milner *et al.* (1968) high population of invertebrate herbivores create some problem for measuring net primary

production in the grasslands. Their biomass estimation revealed (Table V 15) that the Orthopterans are main contributors of the total consumer biomass. High relative humidity and moderate temperature are suitable for the activity of the most of the Orthopterans, which support the observation of Mathur et al. (1956). Therefore, it is concluded that the value of aboveground phytomass would have been more, if there would have been no consumption by these herbivores, affecting in turn the net production.

Milner et al. (1968) further stated that an estimation of the amount of organic production removed by large grazing animals is of significant importance. Therefore, a survey of large grazers visiting the grazed stand was made and net herbage removed by them was calculated following the formula proposed by Mehta (1977). It was observed that about 56% of the aboveground net production of protected stand was removed by grazing livestock. The present observation supports the findings of Odum (1966).

The present investigation clearly revealed the impact of grazing on aboveground and underground phytomass, its ratio and net production.

The occurrence of peak aboveground and underground phytomass values in different months on the two stands, under the same climatic conditions, clearly indicated grazing influence.

The U.G./A.G. phytomass ratio has been given due importance by Ronald (1978) and Billore (1978). They have observed an increase in the ratio as a result of grazing. In the present investigation also higher U.G./A.G. ratio was obtained on grazed stand than protected. This higher ratio indicated a higher proportion of organic matter stored in underground phytomass than aboveground on grazed stand.

Under the same climatic condition, the difference in the net production values of the two stands is supposed to be due to grazing influence of large herbivores.

Thus it is concluded that the community under grazing pressure suffer a loss in organic matter more than the amount removed by large herbivores, obviously due to the damaging effects of defoliation and tramplling of the plant species (Misra, 1968).

The calorific value of plant material depends upon the quality and quantity of reserve food in it. Further, the energy content of a plant or its components are governed by its fat content or nutritive status and also its genetic constitution; and stage of life history. Among the plant compounds which store energy are carbohydrates, proteins and lipids.

Accumulation of energy significantly depends on the climatic conditions and the response of the plants. In the

present investigation maximum energy was accumulated in the aboveground standing component during rainy season. There is a gradual decline in the energy values from standing live to standing dead, underground and litter component due to weathering and decay of organic matter. This is in conformity with the findings of Golley (1965), Jain (1971), Das (1974), Trivedi (1976) and Singh (1978). The energy stored in the plant material was transferred to the floor through litter fall as a result of death of annuals and gradual drying of perennials. The energy thus transferred through litter fall was released to the soil by the decay and decomposition of litter due to the activity of microbs inhabiting the soil. Maximum percentage of release of energy was found in rainy season.

The overall average caloric value obtained in the present investigation is well within the range of other tropical grassland communities. The value is very similar to Varanasi, Gorakhpur and Sagar grasslands (Table VI 6). The variations in overall average caloric values of different communities has been explained by McNair (1945), as with the increasing altitude, latitude and decrease in temperature, there was a corresponding increase in fat content, resulting into high caloric values.

The high value of efficiency (1.46%) of energy capture was found in the present investigation, indicating the grass-

land community have a high potential for capturing solar radiation. This efficiency of energy capture is much greater than in the temperate grasslands and some tropical grasslands (Table VI 7). The high efficiency values have also been reported by Singh and Misra (1968), Singh (1972b), Pandeya (1974), Singh and Yadav (1974) and Saxena *et al.* (1974). Thus the present grassland community is more efficient as compared to grasslands of Ujjain (Misra, 1973), Gorakhpur (Asthana, 1974) and Jhansi (Trivedi, 1976).

The year long growing season, abundant precipitation, high light intensity and preponderance of C_4 plants in tropical grasslands seems to favour greater efficiency of energy capture.

SUMMARY

In the present investigation two stands in a forest grassland were taken for study. First was protected against grazing by large herbivores during the study period and in the second grazing was allowed throughout the year.

Computation of water balance of the study area was made following the method proposed by Thornthwait and Mather (1955) and the ecoclimatic formula arrived at was $C_1\ A_2'a_2'\ s$.

Floristic composition of these stands revealed higher number of species (70) on protected stand than (60) grazed. Life form classes indicate a Therophytic nature of these stands. The percentage species in the five frequency classes showed heterogenity in the grassland studied.

The standing crop of aboveground plant material showed maximum value (1590.61 g/m^2) in October on protected stand and (403.03 g/m^2) in September on grazed. The percentage contribution of grasses ranged from 90 to 99% and21 to 96% respectively on the two stands.

The underground phytomass showed maximum value (790.12 g/m^2) in November on protected and (318.36 g/m^2) in October on grazed stands.

The U.G./A.G. phytomass ratio remained always less than one except in May on protected stand, while it increased to more than one throughout winter and summer on grazed stand. Vertical stratification of aboveground phytomass gave the appearance of an upright pyramid reaching to a height of 1-50 metres.

Greater Leaf area index and photosynthetic phytomass was recorded during rainy season. Maximum L.A.I. (6.26 m^2/m^2) was obtained in August. Maximum chlorophyll concentration (3.81 mg/mg^{-1}) was recorded in July. But the maximum chlorophyll content on ground area basis was obtained (1.26 g/m^2) in August.

Aboveground net production was obtained as 1763.08 g/m^2 and 448.76 g/m^2; and underground net production as 630.98 g/m^2 and 320.76 g/m^2 on protected and grazed stands respectively. Total net production worked out are 2394.06 g/m^2 for protected and 769.52 g/m^2 for grazed stands respectively. It was recorded that the present protected grassland is highly productive (23 ton/ha/yr) than some other tropical grasslands.

Statistical relationship between structural and functional aspects revealed a negative relationship between diversity index and dominance index, net production and stability and dominance index and net production. While a positive relationship was found between dominance index and stability.

Litter disappearance revealed higher rate during rainy season on protected stand. In contrast to this, maximum litter disappearance rate was recorded in winter season on grazed stand. Turnover rate of litter was found higher ($0.95^{10^{-2}}$/day) on grazed stand than ($0.66^{10^{-2}}$/day) protected.

Organic matter dynamics revealed total net production at the rate of 6.5 g/m^2/day and 2.1 g/m^2/day for protected and grazed stands respectively. Total disappearance rate worked out are 2.7 g/m^2/day and 1.2 g/m^2/day for both the stands. Thus about 41% and 57% of net annual production of the two stands respectively, is released from different compartments for heterotrophic consumption.

Maximum biomass (12.60 g/m^2) of invertebrate herbivores was recorded in August on protected stand. Net herbage removed from grazed stand by large herbivores was calculated as about 56% of the aboveground net production of protected stand.

In the present investigation maximum energy was accumulated in the aboveground standing component during rainy season. There was a gradual decline in the energy values from standing live to standing dead, underground and litter component. The high value (1.46%) of efficiency of energy capture was found in the present investigation, indicating the grassland community has a high potential for capturing solar radiation.

The annual net energy fixed by the grassland was 10948.9 K cal/m^2/yr and annual disappearance was 4327.0 K cal/m^2/yr which revealed that about 40% of the total energy fixed by the community disappeared from the system.

REFERENCES

Agnihotri, G.K. 1979. Ecological studies of some grasslands of Mandla. Ph.D. Thesis, University of Saugar, Sagar.

Agrawal, V.K. 1970. Monthly variation in the standing crop, annual net production and nutrient turnover in some species of the tropical grassland communities at Varanasi. Ph.D. Thesis, B.H.U. Varanasi.

Ambashta, R.S. 1969. A text book of Plant Ecology.

__________ 1971. Conservation ecology. Proc. School on Plant ecology (Ed. Misra, R. and R.R. Das) Oxford and I.B.H. Calcutta.

__________ and A.N. Maurya, 1968. Ecology of the Banaras Hindu University grasslands. Abst. Proc. Nat. Sci. (India).

__________, __________ and U.N. Singh, 1972. Primary production and turnover in certain protected grasslands of Varanasi, India. Tropical Ecology with an emphasis on organic production. Golley and Golley Ed. pp. 43-50 Athens, Georgia, University of Georgia.

Anderson, F. 1971. Methods and preliminary results of estimation of biomass and primary production in a south Swedish mixed deciduous woodland. In: Productivity of forest ecosystem. P. Dwigneaud, Ed. pp. 281-288.

Arnon, D.J. 1949. Copper enzyme in isolated chloroplast. Pt. Physiol., 24: 1-15.

Asthana, M. 1974. Studies on phytosociology, primary productivity and energetics of a grassland at Gorakhpur. Ph.D. Thesis, Gorakhpur University, India.

Balapure, K.M. 1954. Reproduction capacity of six grasses. M.Sc. Thesis, Saugar University, Sagar.

Barrat, B.C. 1965. Decomposition of grass litter in three kinds of soil. Plant and Soil, 23: 265-269.

Beavington, F. 1969. Upland grass production in North-East Scotland in relation to soil and site conditions. J. Brit. Grassland Soc., 24: 31-39.

Bharucha, F.R. 1952. The grasslands of Raita, Bombay. Jour. Brit. Grassland Soc., 7: 55-63.

__________ and R.N. Dave, 1944. The biological spectrum of a grassland association. J. Univ. Bombay, 13: 15-17.

__________ and K.A. Shankarnarayan, 1958. Studies on the grasslands of the Western Ghats, India. J. Ecol., 46:681-705.

Billore, S.K. 1973. Net primary production and energetics of a grassland ecosystem at Ratlam, India. Ph.D. Thesis, Vikram University, Ujjain, India.

Billore, S.K. 1978. Ecology of grazing lands with reference to their structure and functional attributes. D.Sc. Thesis, Vikram University, Ujjain.

__________ and L.P. Mall. 1976. Seasonal variation in chlorophyll content of a grassland community. Trop. Ecol., 17(1): 39-44.

__________ and ________ 1977. Dry matter structure and its dynamics in Sehima grassland community II. Dry matter dynamics. Trop. Ecol., 18: 29-35.

__________, __________ and V.P. Singh. 1975. Intercomparison of methods for primary production measurement in harvest technique. Geobios,2: 80-81.

Bliss, L.C. 1956. A comparison of plant development in micro-environment of arctic and alpine Tundras. Ecol. Mongr., 26: 303-337.

__________ 1966. Plant productivity in alpine micro-environment. Ecol. Monogr., 36: 125-155.

Bore, N.L. 1960. The grasses of Burma, Ceylon, India and Pakistan. Porgamon Press, Oxford, London, pp. 767.

Bourline, F. and M. Hadley, 1970. The ecology of tropical savannas. In Ann. Rev. Ecol. Syst. Vol. 1: 125-152.

Bray, J.R. 1960. The chlorophyll content of some native and managed plant communities in central Minnessota. Can. J. Bot., 38: 313-333.

Bray, J.R. 1963. Root production and the estimation of net production. Can. J. Bot., 41: 65-72.

*__________, Lawrence, D.B. and L.C. Pearsòn, 1959. Primary production in some Minnesota terrestrial communities. Oikos, 10: 38-49.

Cain, S.A. 1950. Lifeforms and phytoclimate. Bot. Rev., 16: 1-32.

Chakradeo, G.M. 1922. An ecological study of Deccan grasslands II. Proc. 9th Indian Science Congress, Madras, 119-120.

Champion, H.G. 1936. A preliminary survey of the forest types of India and Burma. Ind. Forest. Res. (N.S.) 1: 1-286.

Chatterjee, B.N., S.C. Mandal and S.J. Alam, 1954. Studies on the growth of some grasses and legumes and their associations for pastures in Bihar. J. Soil water Conser. India, 3: 14-20.

Chaudhary, V.B. 1967. Seasonal changes, annual net production and Energetics of <u>Dichanthium</u> <u>annulatum</u> stands. Ph.D. Thesis, B.H.U. Varanasi, India.

__________ 1972. Seasonal changes in the standing crop and net aboveground production in <u>Dichanthium</u> <u>annulatum</u> grassland at Varanasi. Symp. Trop. Ecol. with an emphasis on organic productivity, pp. 51-58. (Ed. Golley P.M. and F.B. Golley).

Curtis, J.T. and G. Cottom, 1962. Plant Ecology work book-Laboratory field and reference manual. Burgess Publ. Co. Minneapolis, Minn. U.S.A.

__________ and R.P. McIntosh, 1950. The interrelations of certain analytic and synthetic phytosociological characters. Ecology, 31: 434-455.

Dabadghao, P.M. and S.M. Sikka, 1961. Forage crops and grasses. Hand Book of Agriculture, I.C.A.R. New Delhi, 260-297.

__________ and K.A. Shankarnarayan, 1973. The grass cover of India. I.C.A.R., New Delhi.

Dahlman, R.C. and Kucera, C.L. 1965. Root productivity and turnover in native praire. Ecology, 46: 84-89.

Dakwale, R.N. 1975. A study of Biogeochemical cycles in grassland ecosystem. Ph.D. Thesis, University of Saugar, Sagar.

Das, L.K. 1975. Biomass structure and net primary productivity in a grassland ecosystem at Allahabad. Geobios, 2: 147-149.

Das, R.D. 1974. Seasonal changes in standing crop, clipping effect on net primary production, disappearance rate of dead material and energy content of a grassland community at Raipur. Ph.D. Thesis, Ravishanker University, Raipur.

Daubemire, R. 1959. Plant and Environment. John. Wiley and Sons. Inc., New York. 422 p.

__________ 1972. Some ecological consequences of converting forest to savanna in North Western costa Rica. Trop. Ecol., 13(1): 31-51.

Dittmer, H.J. 1973. Clipping effects on Bermuda grass biomass Ecology, 54(1): 217-219.

Dwivedi, R.S. 1970. A comparative study of energetics and cycling of phosphorus using 32 p. in wheat (*Triticum aestivum* L.) and Marvel grass (*Dichanthium annulatum* (Forsk) Stapf). Ph.D. Thesis, B.H.U. Varanasi, India.

Eastin, J.D. and C.Y. Sullivan, 1969. CO_2 exchange in compact and semiopen *Sorghum* inflorescence crop. Science, (9: 165-166.

F.A.O. 1973. Production year book 1972. Vol. 26. Food and Agriculture organization, United Nations, Rome.

Gaussen, H. 1960. Ombrothermic curve and xerothermic index. Trop. Ecol.,1: 25-26.

Gill, J.S. 1975. Herbage dynamics and seasonality of primary productivity at Pilani, Rajasthan. Ph.D. Thesis, B.I.T.S., Pilani.

Goldsworthy, A. 1970 Photorespiration. Bot. Rev., 36: 321-340.

Golley, F.B. 1959. Table of caloric equivalents. Mimeo. p. 7.

__________ 1961. Energy values of ecological materials. Ecol., 42: 581-584.

__________ 1965. Structure and function of an old field broomsedge community. Ecol. Mongor., 35: 113-131.

__________ 1972. Tropical ecology with an emphasis on organic production, 407-418. Univ. Georgia, Athens, Georgia.

__________ 1975. Tropical ecological systems. Ecological Studies II. Springer Verlag, New York.

__________ and J.B. Gentry, 1966. A comparison of variety and standing crop of vegetation on one year and a twelve year abondoned field. Oikos, 15: 185-199.

__________ and H. Lieth, 1972. The basis of tropical production. Tropical Ecology (Ed. Golley,P.M. and F.B. Golley), New Delhi Symposium Vol. 1-26.

Gorham,E. 1959. Chlorophyll derivatives in woodland soils. Soil Sci., 87: 258-261.

__________ and J. Sanger, 1967. Plant pigments in woodland soils. Ecology, 48: 30-308.

Gosz, J.R., G.E. Likens and F.H. Bormann, 1972. Nutrient content of litterfall on the Hubbard Brook Experimental Forest, New Hampshire, Ecol.,53:769-784.

Govindu, H.C. and M.J. Thirumalachar, 1952. Grasslands of Mysore. Tech. Bull. Coll. Agric. Bangalore, p. 197.

Grodins, F.S. 1963. Control theory and Biological systems, Columbia University Press, New York, 205 p.

Gupta, R.K., Saxena, S.K. and S.K. Sharma, 1972. Aboveground productivity of grasslands in a community of Prosopis cineraria at Jodhpur, Rajasthan. Communicated, I.S.T.E., INTECOL- INSA. Symp. on Tropical Ecology with an emphasis on organic productivity (Ed. Golley, P.M. and F.B. Golley).

Gupta, S.K. 1972. Energy structure of standing crop in certain grassland at Gyanpur. Trop. Ecol., 13: 89-95.

Gupta, S.R., 1976. An ecological study of Themeda quadrivalvis type of grassland of Bundelkhand region. Ph.D. Thesis, University of Saugar, Sagar.

__________ 1978. Relationship between phytosociological attributes and aboveground biomass in a grassland community. Geobios, 5:105-107.

Gupta, S.R. and J.S. Singh, 1977. Decomposition of litter in a tropical grassland. Pedobiologia, 17: 330-333.

Hadley, E.B. and L.C. Bliss, 1964. Energy relationship of alpine plants on Mt. Washington, New Hampshire. Ecol. Monogr., 44: 331-357.

Hadley, E.B. and B.J. Kieckhefer, 1963. Productivity of two prairie grasses in relation to five frequency. Ecol., 44: 389-395.

Haines, B. and R.B. Foster, 1977. Energy flow through litter in a Panamanian forest. J. Ecol., 65: 147-155.

*Helms, J.A. 1965. Diurnal and seasonal patterns of net assimilation in Douglas fir, Pseudotsuga Menziesii (mirb). Franco, as influence by environment. Ecology, 46: 688-708.

Innis, G.S. 1973. Analysis of structure, function and utilization of grassland ecosystem. Progress report, U.S. I.B.P., Grassland Biome, Vol. II (Ed. Van Dyne,G.M.)

* ________ 1978.(Ed.) Grassland simulation Model. Ecological studies No. 26 Springer Verlag. New York, 298 p.

*Iwaki, H., Midosikawa, B. and K. Hogestu, 1964. Seasonal changes in standing crop. Bot. Mag, Tokyo, 77: 447-457.

Jain, H.K. 1977. Ecosystem analysis of grassland near Rajkot. Ph.D. Thesis, Saurashtra University, Rajkot.

Jain, N.K. 1963. The effect of decomposition of mature leaves and litters of Sal (Shorea robusta) on garden and lateritic soil. Proc. Nat. Acad. Sci., 33: 148-152.

Jain, N.K. 1971. Studies on some grazed grasslands of Jodhpur. In: Proceddings of the School on Plant Ecology. (Ed. Misra, R. and R.R. Das). Oxford and I.B.H. Publishers, Calcutta.

__________ 1974. Patterns of area changes in open grasslands during rainy season. J. Indian Bot. Soc., 53: 34-40.

Jain, S.K. 1970. Vertical distribution of underground biomass and turnover. Bull. Bot. Soc., Univ. of Saugar, Sagar, 17: 51-56.

__________ 1971. Production studies in some grasslands of Sagar. Ph.D. Thesis, Univ. of Saugar, Sagar.

__________ 1977. Aboveground plant biomass and net community productivity in Setaria glauca. Beauv. grassland at Sagar. J. Indian Bot. Soc., 56(III): 228-232.

__________ and R.N. Dakwale, 1971. Underground productivity and turnover in Heteropogon contortus Romet. Schutt. grassland. I.S.T.E., INTECOL - INSA. Symp. on Tropical Ecology with an emphasis on organic productivity, New Delhi.

__________ and G.P. Mishra, 1969. Seasonal changes in net aerial phytomass in grassland at Sagar (M.P.). Symp. Plant Productivity studies in India, 57th Ind. Sci. Cong., Kharagpur.

Jain, S.K. and G.P. Mishra, 1972. Changes in underground biomass and annual increment in an upland grassland of Sagar. Trop. Ecol., 13: 131-138.

*Jankowska, K. 1968. Methods for estimation of disappearance rate of dead plant parts as a basis for estimation of net primary production. In: p. 8 Nat. Comm. working group on primary productivity, P.T. Section (Ed. A. Medweeka) Kornas.pp. 14-200.

Jenny, H., S.P. Gessel and F.T. Bingham, 1949. Comparative study of decomposition rates of organic matter in temperate and tropical regions. Soil Sci., 68:419-432.

*Jones, G.N. 1936. A botanical survey of the olympic penisula, Washington University of Washington. Publ. in Biol., 5.

Joshi, M.C. 1978. An ecological approach of the desert ecosystem in Shekhawati, Rajasthan. Glimpses of Ecology, p. 239-262.

__________ B.C. Nigam, R.V. Babu and A. Kumar, 1971. Primary productivity studies of two desert plants and a few selected sites in and around Pilani, Rajasthan. In: Golley and Golley (Ed.) Tropical Ecology with an emphasis on organic production. University of Georgia Press.

Kandya, A.K. 1974. Organic matter dynamics in four selected forest tree species of Sagar. Ph.D. Thesis, Univ. of Saugar, Sagar.

*Kemp, C.D. 1960. Methods of estimating the leaf area of grasses from linear measurements. Ann. Bot. London 24: 491-499.

Koelling, M.R. and C.L. Kucera, 1965. Production and turnover relationship in native tall grass prairie. Lowa state. J. Sci., 39: 387-392.

Kumar, L.S.S. 1946. Better utilization of forest grasslands in Bombay province. Indian For., 72: 162-164.

Kumar, A. 1971. Structure and net community production of the terrestrial herbaceous vegetation of certain sites in and around Pilani with special emphasis on grasses. Ph.D. Thesis, B.I.T.S., Pilani.

__________ and M.C. Joshi, 1972. The effect of grazing on the structure and vegetation near Pilani, Rajasthan. J. Ecol., Bull., 211: 28 p.

__________ and __________ 1972. The effect of grazing on the structure and productivity of vegetation near Pilani, Rajasthan. Ind. Jour. Ecol., 60: 665-675.

Lewis, J.K. 1969. Primary producers in grassland ecosystems. Range Sci. Dept. Sci. Ser., No.2 Colorado State University, Fort Collins.

__________ 1971. The grassland biome. A synthesis of structure and function. In: Preliminary analysis and structure and function in grasslands (Ed. by N.R.

French) Range Sci. Dept. Sci. Ser. No. 10, Colorado state University, Fort Collins, pp. 317-387.

Lieth, H. 1968. The measurement of calorific values of biological material and the determination of ecological efficiency. In: Functioning of terrestrial ecosystem at the primary production level. F.E. Eckardt. Ed. 233-242 pp, UNESCo, Paris.

__________ 1971. The determination of plant dry matter production with special emphasis on the underground parts. In: (F.E. Eckardt. Ed.) Functioning of terrestrial ecosystem at primary production level. UNESCO, Paris.

__________ 1972b. The net primary production of earth with special emphasis on the land areas. In: Perspectives of primary productivity of the earth (Ed. R.H. Whittaker) Symp. at the Ameri. Inst. of Bio. Sci. II National Congress Miami, Forida.

__________ and R.H. Whittaker, 1975. Primary productivity Biosphere. Ecological studies in Springer Verlag, New York.

Lomnicki, A.E.,Banadola and K. Jankowska, 1968. Modification of Weigert Evans method for estimation of net primary production. Ecol., 49: 147-149.

Long, F.L. 1934. Application of calorimetric methods to ecological research. Plant Physiol., 9: 323-337.

Madge, D.S. 1965. Leaf fall and litter disappearance in a tropical forest.Pedobilogia, 5: 273-288.

__________ 1969b. Litter disappearance in forest and savanna. Pedobiologia, 9: 288-299.

Mall, L.P. 1975. Grasslands, their ecology and management with special reference to Madhya Pradesh. Presidential address, M.P. Vigyan Academy.

__________ and S.K. Billore, 1974. An indirect estimation of litter disappearance in grassland study. Curr. Sci., 43: 506-507.

__________ and V.P. Singh, 1971. Seasonal variation in the standing biomass, total annual production and caloric energy of Iseilema, Indigofera community of grassland, Ujjain (M.P.) India. In: J.S.T.E.

__________, S.K. Billore and C.M. Misra, 1973. A study on the community chlorophyll content with reference to height and dry weight. Trop. Ecol., 14: 81-83.

__________, C.M. Misra and S.K. Billore, 1973. Primary productivity of grassland ecosystem at Ujjain and Ratlam districts of M.P., Progress report INSA Project, School of Studies in Botany, Vikram University, Ujjain, India pp. 1-30.

Malone, C.R. 1968. Determination of peak standing crop biomass of herbaceous shoots by the harvest method. Amer. Midl. Nature, 79: 429-435.

Margalef, R. 1965. Ecological correlations and the relationship between primary productivity and community structure. Mem. I Ital. Idrobiol., 18: 355-364.

Marwah, P. and R.S. Ambashta, 1972. Community architecture and productivity of wheat crop. Trop. Ecol.,13(2): 176-182.

Mathur, S.N., P.K.B. Menon and S.R.V. Rao, 1956. Insect fauna of Pilani. Proc. Rajasthan Acad. Sci., 6:20-23.

Maurya, A.N. 1970. Ecology of Varanasi grasslands with reference to two common species. Ph.D. Thesis, B.H.U. Varanasi.

McIntosh, R.P. 1967. An Index of diversity and the relation of certain concepts to diversity. Ecol.,48: No. 3, 392-404.

Mc Nair, J.B. 1945. Plant fats in relation to environment and evolution. Bot. Rev., 11: 1-59.

*Mc Naughton, S.J. 1967. Relationship among functional properties of California grasslands. Nature, London, 216: 168-169.

Mehta, S.C. 1977. Ecology of grazing lands with reference to impact of grazing and fire on primary production. Ph.D. Thesis, Vikram University, Ujjain.

Meyer, B.S., D.B. Anderson and R.H. Bohning, 1969. Introduction to plant physiology. D. Van. Nostrand Co., Inc.: 541 p.

Milner, C. and R.E. Hughes, 1968. Methods of measurement of the primary production of grassland. I.B.P. Hand book No. 6 Blackwell, U.K. 70 p.

Mishra, G.P. and S.P. Bajpai, 1971. Biomass studies in grassland of Sagar. Bull. Bot. Soc., Univ. of Saugar, Sagar, 17-18: 25-30.

__________ and S.K. Jain, 1974. Study on community energetics in Heteropogon contortus grassland of Sagar (M.P.). Proc. 61st Ind. Sci. Cong., Part III, Abs. Sec. VI. BOT.

Misra, C.M. 1973. Primary productivity of a grassland ecosystem at Ujjain, India. Ph.D. Thesis, Vikram University, Ujjain, India.

Misra, C.M. and L.P. Mall, 1974. Energy storage and transfers in tropical grassland community. Trop. Ecol., 15: 22-27.

__________ and __________ 1975. Architecture and standing biomass of a grassland community. Ann. Arid. Zone 14: 119-123.

__________ and __________ 1975. Photosynthetic structure and standing biomass of a grassland community. Trop. Ecol., 16: 76-80.

Misra, G. 1980. Growth characteristics of certain grasses in response to clipping and moisture stress. Ph.D. Thesis, B.H.U. Varanasi, India.

Misra, R. 1946. Autecological study of the vegetation of the B.H.U. grounds. J.I.B.S., 25: 39-59.

__________ 1955. The vegetation of Sagar. Symp. Vegetation types of India.

__________ 1957. Ecological studies in Madhya Pradesh. Presidential address 27th Session National Academy of Science, Biological Section.

__________ 1959. Status of the plant communities in the upper gangetic plains. J.I.B.S., 38: 1-7.

__________ 1968. Ecology work book. Oxford, I.B.H. Publishing Co., New Delhi, India, pp. 1-244.

__________ 1969. Primary production of Chakia forest and I.B.P./P.T. study of organic productivity and nutrient cycling in monsoon forest, grasslands and croplands. Paper No. 1 and 2, 11th Tech. Meeting IUCN, New Delhi, India.

__________ and B. Gopal, 1968. (Ed.) Proceedings of the Symposium on Recent Advances in tropical ecology. I.S.T.E. Varanasi.

__________ and K.P. Singh, 1970. Ecology in India. A bird eye view. Golden Jubl. Vol. J.I.B.S., 7: 1-20.

__________ and N.K. Joshi, 1952. Forest complex of Patharia Hills, Sagar, M.P. J.I.B.S., 31: 15-170.

*Monk, C. 1966. Ecological importance of root/shoot ratios. Bulletin of the Torrey Botanical Club., 13: 402-406.

*Monsi, M. and Saeki, 1953. Uberden Lichtfaktor in den Pflanzengesellschften and seiens. Bedeutung furdie. Stoffprodiktion. Trop. J. Bot., 14: 22-52.

Naik, M.L.1973. Ecological studies of some grasslands of Ambikapur. Ph.D. Thesis, Ravishankar University, Raipur.

__________ and G.P. Mishra, 1974. I. Structure of the grasslands. Trop. Ecol., 15 (1&2): 77-89.

__________ and __________ 1976. Ecological studies of some grasslands of Ambikapur. II. Rate of disappearance of the dead plant parts. Trop. Ecol., 17(2): 95-99.

__________ and __________ 1977. Net community productivity and efficiency of the grasslands. Trop. Ecol.,18(1): 52-59.

Nandpuri, K.S.,J.C. Kumar, J.S. Kanwar and Himmat Singh,1973. Varietal difference in chlorophyll pigmentation in carrot. J. Res. P.A.U., 10(4): 430-432.

__________, __________ and ______ 1973. Evaluation of chlorophyll pigmentation in some varieties of radish. J. Res. P.A.U., 10(4): 365-368.

__________, B.N.,Sharma,J.C. Kumar and Yashpal, 1976. Differences in chlorophyll pigmentation in the varieties of Turnip. J. Res. P.A.U., Vol. XIII No. 4.

Odum, E.P. 1960. Organic production and turnover in old field succession. Ecol., 41: 34-49.

__________ 1962. Relationship between structure and function in the ecosystem. Jap. J. Ecol., 12: 108-118.

__________ 1963. Ecology. Hott, Rinehart and Winston, New York (Modern Biology Series).

__________ 1971. Fundamentals of ecology. 3rd Ed. Saunders Co., Philadelphia, 574 p.

Olson, J.S. 1963. Energy storage and balance of producers and decomposers in ecological systems. Ecology, 44: 322-331.

Ovington, J.D. 1965. Organic production, turnover and mineral cycling in woodlands. Biol. Rev.,40: 293-336.

__________ and D. Heitkamp, 1960. The accumulation of energy in forest plantation in Britain. J. Ecol., 48: 639-646.

__________, __________ and D.B. Lawrence, 1963. Plant biomass and productivity of prairie, savannah, Oak wood and maize field ecosystem in central Minnesota. Ecol., 44: 52-63.

Pandey, T.N. 1977. Measurement of the rate of primary production in a Varanasi grassland. Ph.D. Thesis, B.H.U. Varanasi.

Pandeya, S.C. 1950. Notes on autecology of Dichanthium annulatum Stapf. and Bothriochloa pertusa (A) Camus. J. Bot. Soc., Univ. of Saugar, Sagar, 3: 3-10.

__________ 1952. Grasslands of Sagar, M.P. Ind. For., 78: 654-678.

__________ 1953: Ecological studies of grassland of Saugar. Ph.D. Thesis, Univ. of Saugar, Sagar.

__________ 1960. Status of M.P. grasslands. Bull. Inter. Soc. Trop. Ecol., 1: 30.

__________ 1961. On some new concepts in phytosociological studies of grasslands. J. Ind. Bot. Soc., 40: 267-270.

__________ 1962. Status of grassland of Madhya Pradesh. Ind. Trop. Ecol., 3: 101-106.

__________ 1964a. Ecology of grasslands of Sagar, M.P. II A. composition of the fenced grassland association. J. I.B.S., 43: 577-605.

__________ 1964b. Ecology of grasslands of Sagar, M.P. II B. composition of the associations open to grazing on occupying special habitat. J.I.B.S., 43: 606-639.

__________ 1969. Ecology of grassland of Sagar, M.P. III. Edaphic factors in distribution of grassland association. Trop. Ecol., 10: 163-182.

__________ 1974. Dynamics of primary production of grazing land and forest ecosystem in western India. Proc. 1st Int. Congr. Ecol., : 46-61.

Pandeya, S.C. and H.K. Jain, 1974. Ecosystems self regulations and control of mineral cycling in a protected grazing land. ecosystem at Rajkot. Proc. XII Inter. Bot. Cong. Symp. 12.

__________ and ________ 1975. State of knowledge report on grazing land ecosystems of Indian sub continent and Sri Lanka compiled for UNESCO, Dept. of BioSciences, Saurashtra University, Rajkot, India.

__________ and P.K. Jayan, 1970. Productivity of natural grasslands dominated by <u>Cenchrus ciliaris</u> at Ahmedabad.

__________, S.C. Sharma, S.J. Pathak, H.K. Jain, K.C. Paliwal and V.M. Bhanot, 1973. Autecology and Geneecology of Anjan grass (<u>Cenchrus ciliaris</u>) complex Second Progress report.

__________, __________, __________ and ________ 1977. The environment of Cenchrus grazing lands in Western India. Final report of research project on, Autecology and Geneecology of Anjan grass (<u>Cenchrus ciliaris</u>) complex in Western India. Dept. of Biosciences, Saurashtra University, Rajkot, India.

__________, G.S. Puri and J.S. Singh, 1968. Research methods in Pt. Ecology. Asia Publishing House, Bombay.

Park, T. 1946. Some observations on the history and scope of population ecology. Ecol. Monogr., 16: 313-320.

Pathak, P.S., R. Debroy and B.K. Trivedi, 1974. Aboveground dry matter production in tropical dry deciduous forest grassland of Bundelkhand forest division, Paper presented at I.B.P. grassland biome, Synthesis, Symp. held at Varanasi.

Patten, B.C. 1959. An introduction to cybernetics of the ecosystem. The Tropic dynamic aspect. Ecol., 40: 221-231.

Pearson, L.C. 1965. Primary production in grazed and ungrazed desert community of eastern Idaho. Ecol., 46: 285-288.

__________ 1966. Primary production in a northern desert area. Oikos, 15: 211-228.

Phillipson, J. 1966. Ecological energetics. St. Martins Press, New York, pp. 57.

Prasad, S.K. 1956. Problem of grazing in Bihar. Improvement and protection of grazing areas. Ind. For., 82: 39-42.

Puri, G.S. 1961. Grasslands of Western India. Gosamvardhan, 8: 1-6.

Radharani, S. 1976. Structure and functioning of Cynodon Dactylon community. Ph.D. Thesis, B.H.U., Varanasi.

Raman, S.S. 1960. Root ecology of Dichanthium annulatum Stapf. J.I.B.S., 2: 210-217.

Raman, S.S. 1966. Organisation of grass communities on Western and Vindhyan uplands of Varanasi district, J.I.B.S., 3: 266-276.

Ramdeo, K.D. 1970. Phytosociological studies on the vegetation of Udaipur, Southeast Rajasthan. J.I.B.S., 13: 13-25.

Ramkrishnan, P.S. 1958. Contribution to the ecological flora of Varanasi district. Ph.D. Thesis, B.H.U. Varanasi.

Ranganathan, C.R. 1938. Studies in the ecology of Shola grassland vegetation of Nilgiri plateau. Ind. For., 64: 523-548.

*Raunkiaer, C. 1934. The life forms of plants and statistical plant geography. The Cidrendon Press, Oxford pp. 632.

Raychoudhary, S.P. and T.S. Biswas, 1957. A suggested procedure for classification of grasslands in India. J. Soil Water Conser. India, 5: 118-119.

Rebeiz, C.A. and P.A. Castelfranco, 1973. Protochlorophyll and chlorophyll biosynthesis in cell free system from higher plants. Ann. Rev. Pt. Physiol., 24: 129-172.

Reice, S.R. 1974. Environmental patchness and the breakdown of leaf litter in a woodland stream. Ecology, 55: 1271-1282.

Robertson, J.H. 1933. Effect of clipping on the development of certain grass seedlings. Plant Physiol., 8: 425-447.

Ronald, H.S. 1978. Plant phenology and biomass dynamics. In: grassland simulation model. (Ed. C.S. Innis) Ecological studies, 26, Springer Verlag, New York.

Sanger, J.E. 1971. Quantitative investigation of leaf pigments from their inception in buds through autumn. Coloration to decomposition in falling leaves. Ecology, 52: 1075-1089.

Saxena, S.K., R.K. Gupta, S.K. Sharma and B. Ram, 1974. Productivity of natural grasslands and three desert grass species, Jodhpur, India.

*Shankarnarayan, K.A. 1956. Phytosociological and ecological studies of grassland of Bombay. Ph.D. Thesis, Bombay University, Bombay.

__________ 1958. Vegetation of Nilgiris. I. Sholas and grasslands. J. Biol. Sci., I: 90-98.

__________ and P.M. Dabadghao, 1970. Ecological studies on the grassland of Jhansi, U.P. Ann. Arid. Zone, 9: 54-63.

Shukla, A.N. 1976. Fungal decomposition of Sal leaf litter in Varanasi forest. Ph.D. Thesis, B.H.U. Varanasi.

*Sims, P.L. and J.S. Singh, 1971. Herbage dynamics and net production in certain ungrazed and grazed grasslands in North America. Range Sc. Dept. Sci. Ser., 10: pp. 59-124, Colorado state Univ. Fort Collins Col.

Singh, A.K. 1972a. Structure, primary net production and mineral contents (N & P) of two grassland community of Chakia hills, Varanasi. Ph.D. Thesis, B.H.U. Varanasi, India.

Singh, A.K. 1978. Comparison of primary productivity and energetics of savanna and teak (Tectona grandis Linn.) Plantation of Chandraprabha Region. Ph.D. Thesis, B.H.U. Varanasi, India.

Singh, J.S. 1967. Seasonal variation in composition, plant biomass and net community production in the grasslands at Varanasi. Ph.D. Thesis, B.H.U. Varanasi, India.

__________ 1968. Net aboveground community productivity in grasslands at Varanasi. In: Proc. Symp. Recent Adv. Trop. Ecol., (Ed. R. Misra and B. Gopal), I.S.T.E. Varanasi 2: 631-654.

__________ 1973. A compartment model of herbage dynamics for Indian tropical grasslands. Oikos, 24: 367-372.

__________ and M.C. Joshi 1977. Primary production in grassland ecosystems of the world. Their analysis and uses. (Ed. R.T. Coupland) Cambridge Univ. Press.

__________ and R. Misra 1968. Efficiency of energy capture by the grassland vegetation at Varanasi. Curr. Sci., 37: 636-637.

__________ and ________ 1969. Diversity, dominance, stability and net production in the grasslands at Varanasi, India. Canad. Jour. of Botany, Vol. 47: pp. 425-427.

__________, W.K. Lauenroth and R.K. Steinhorst, 1974. Review and assessment of various techniques for estimating net aerial primary productivity in grasslands from harvest data U.S./I.B.P. grassland Biome. Colorado State University, Fort Collins, Colorado.

__________ and P.S. Yadav, 1971. Primary productivity in the grassland ecosystem at Kurukshetra. C.S.I.R., Tech. Rep. No. 38(73) 169 G.A.U. II, Kurukshetra, India p. 1-36.

__________ and ________ 1972. Biomass structure and net primary productivity in the grassland ecosystem at Kurukshetra. In: Trop. Ecol., Symp. with an emphasis on organic productivity (Ed. Golley and Golley) pp. 59-74.

__________ and ________ 1974. Seasonal variation in composition, plant biomass and net primary productivity of a tropical grassland at Kurukshetra, India, Ecol. Monogr., 44: 351-376.

Singh, J.S., K.P. Singh and P.S. Yadav, 1977. Static compartment models of energy flow and nutrient cycling In grassland ecosystem of the world, Their analysis and uses (Ed. R.T. Coupland) Cambridge Univ. Press.

Singh, K.P. 1968. Litter production and nutrient turnover in deciduous forest of Varanasi. Proc. Symp. Recent Adv. ,Trop. Ecol., 655-665.

* Singh, R. 1976. Structure and net community production of the herbaceous vegetation in the sand dune regions around Pilani, Rajasthan. Ph.D. Thesis, B.I.T.S. Pilani, Rajasthan.

Singh, U.N. 1972b. Phytosociology and productivity of grazed and ungrazed grasslands of Chakia forest, Varanasi. Ph.D. Thesis, B.H.U., Varanasi.

__________ and R.S. Ambashta, 1975. Energy conserving efficiency of a forest grassland at Varanasi. Acta Botanica Indica, 3: 132-135.

__________ and __________ 1975. Relationship among diversity dominance, stability and net production in an Indian grassland. Ind. Jour. Ecol., 2: No. 2: 110-114.

Singh, V.P. 1969. Ecology of grasslands of Ujjain. Ph.D. Thesis, Vikram University, Ujjain.

Subramanyam, V. 1956a. Climate types of India according to the rational classification of Thornthwaite. Indian J. Met. and Geophys., 7.

Subramanyam, V. 1956b. Water balance of India according to Thornthwaite's concept of potential evapotranspiration Ann. of Asso. Amer. Geogras. 56.

__________ 1958. The role of water balance in climatic research. Bull. Nat. Inst. Sci. India, 11: 101-104.

__________ 1959. Nature and classification of tropical climates with special reference to India. Ind. For., 95(10): 659-669.

*Terrien, J., G. Truffant and J. Carles, 1957. Light, vegetation and chlorophyll. Philosophical Library, New York.

Thornthwaite, C.W. 1948. An approach towards a rational classification of climate. Geographical Review, 38: 55-94.

__________ and J.R. Mather, 1955. Water balance. Publication in Climatology, Drexel Inst. of Tech., 8(1),

*Tieszen, L.L. and E.K. Bonde, 1967. The influence of light intensity on growth and chlorophyll in arctic, subarctic and alpine populations of Deschamsia Caespitosa and Trisetum specatum. Ser. Bio.,25: 1-21.

Tiwari, D.K. 1953. An ecological survey of grasslands of Sagar. Saugar University, Sagar.

Tiwari, S.D.N. 1955. The grasses of Madhya Pradesh, India. Ind. For., 80: 681-689, 81: 602-611.

Tripathi, J.S. 1970. Monthly variation in the standing crop, net production, nutrient content of the species and plant decomposition in a grassland at Varanasi. Ph.D. Thesis, B.H.U. Varanasi, India.

Trivedi, B.K. 1976. Ecological studies of some grasslands of Central India. Ph.D. Thesis, Univ. of Saugar, Sagar.

Trivedi, T.S. 1962. An ecological study of certain grasslands of Sagar with special reference to the underground geological formation. Ph.D. Thesis, Univ. of Saugar, Sagar.

UNESCO, 1973. Expert Panel on Project III Man and the Biosphere Programme. Final report of meeting 2-7 Oct. 1972, MAB, Rept. Ser. 6, UNESCO, Paris, p. 90.

Upadhya, S. 1955. Soil formation under forest cover. Bull. Bot. Soc., Univ. of Saugar, Sagar, No. 7.

Upadhyay, V.S., P.M. Dabadghao and K.A. Shankarnarayan, 1971. Relative grazing values of principal species of Sehima, Dichanthium corer. Ann. Rep. Indian Grassland Fodder Rs. Inst., Jhansi.

*Van Dyne, G.M. 1969. The ecosystem concept in Natural Resources Management. Acad. Press, New York. 383 pp.

________ W.G. Vogel and H.G. Fisser, 1963. Influence of small plot size and shape in range herbage production estimates. Ecology, 44: 746-759.

Van Dyne, G.M., F.M. Smith, J.K. Marshall, J.L. Dodd, D.C. Colemn, J.E. Elis, N.R. French, R.K. Steinhorst and G.S. Innis, 1973. Analysis of structure, function and utilization of grassland ecosystems. Progress Rep., U.S. I.B.P. grassland Biome.

__________, __________, R.L. Czaplewski and R.G. Woodmansee. 1978. Analysis and synthesis of grassland ecosystem dynamics. Glympses of Ecology, 1-80 p.

Varshney, C.K. 1972. Productivity of Delhi grasslands. In: Symp. on Trop. Ecol. with an emphasis on organic productivity. (Ed. Golley and Golley).

Vined Shanker, K.A. Shankarnarayan and P. Rai, 1973. Primary productivity, energetics and nutrient cycling in Sehima, Heteropogon grasslands. I. Seasonal variation in composition, standing crop and net production. Trop. Ecol., 14: 238-251.

Vyas, L.N. 1964. Phytosociological studies on the vegetation of sandy plains of Alwar district. North-east Rajasthan. Trop. Ecol., 5: 60-66.

__________, R.K. Garg and S.K. Agrawal, 1972 . Net above-ground production in monsoon vegetation at Udaipur. In: Proc. Symp. Trop. Ecol., with an emphasis on organic productivity (Ed. Golley and Golley).

__________ and N.L. Vyas, 1978. Net primary productivity of Apluda community on Arawalli Hills at Udaipur. Glympses of Ecology, 111-124 pp.

Watson, D.J. 1958. The dependence of net assimilation rate on leaf area index. Ann. Bot., 22: 37-54.

Weigert, R.G. and F.C. Evans, 1964. Primary production and the disappearance of dead vegetation on an old field in south eastern Michigan. Ecol., 45: 49-63.

Wein, R.W. and L.C. Bliss, 1974. Primary production in arctic communities. Arctic Alpine Res., 6: 261-274.

Whittaker, R.H. 1970. Communities and ecosystem. New York.

Whyte, R.O. 1975. The grassland and fodder resources of India. Sci. Monogr. Indian Counc. Agr. Res. New Delhi, 22: 437.

Williams, A.W. 1966. Range improvement as related to net productivity , energy flow and foliage configuration. J. Rang. Managt., 17: 29-34.

Yadav, P.S. and J.S. Singh, 1977. Grassland vegetation, its structure, function, utilization and management. I. Progress in ecology, Vol. II (Ed. R. Misra, B. Gopal, K.P. Singh and J.S. Singh) Today & Tommorow Printers and Publishers, New Delhi.

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* Not seen in original.